

Progettazione a RadioFrequenza



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Elettronica, Informatica, Telecomunicazioni

***“Seminario d'Introduzione alla
Progettazione a Radiofrequenza e Simulatori”***

D.Zito, 19-20 Maggio 2003 - Parte 1

Sommario

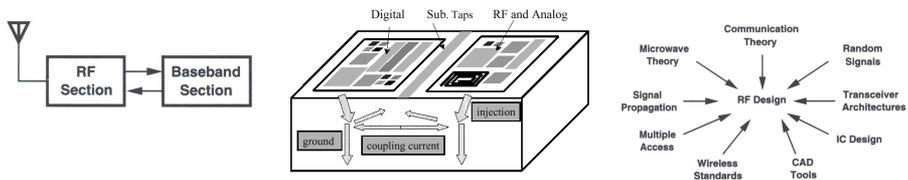
- Introduzione alla Progettazione RF
- Progettazione di Front-end RF
 - Simulazioni Elettromagnetiche
 - Tecnologie e CAD Tools
 - Low Noise Amplifier (LNA)
 - Mixer
- Front-End Multi-Standard per WLAN 5-6 GHz
- Riepilogo e Conclusioni

Introduzione alla Progettazione RF

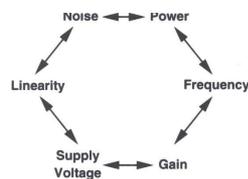
- Aspetti Generali
- Concetti di Base
 - Linearità
 - Noise Figure
- Architetture
 - Eterodina
 - Omodina

Aspetti Generali (1)

- Multidisciplinare



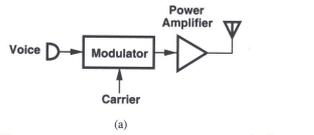
- Trade-Offs



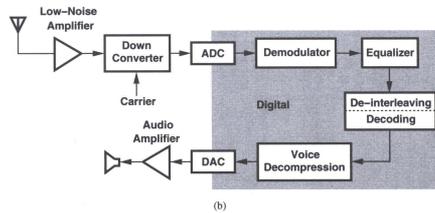
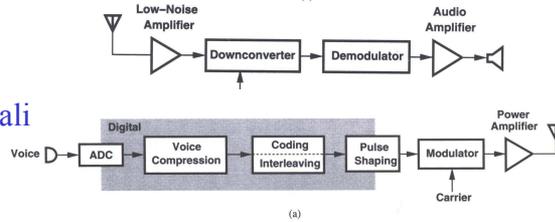
- Design Tools: General to Special Purpose

Aspetti Generali (2)

- Analogici

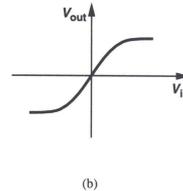
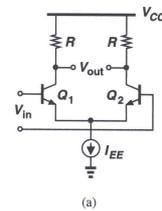


- Digitali



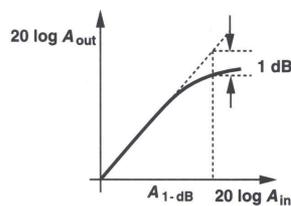
Concetti di Base: Linearità (1)

- Armoniche



$$y(t) \approx \alpha_1 x(t) + \alpha_2 x^2(t) + \alpha_3 x^3(t) = \frac{\alpha_2 A^2}{2} + \left(\alpha_1 A + \frac{3\alpha_3 A^3}{4} \right) \cos \omega t + \frac{\alpha_2 A^2}{2} \cos 2\omega t + \frac{\alpha_3 A^3}{4} \cos 3\omega t$$

- Punto di Compressione a 1dB: CP_{1dB}



Concetti di Base: Linearità (2)

• Intermodulazione

$$x(t) = A_1 \cos \omega_1 t + A_2 \cos \omega_2 t$$

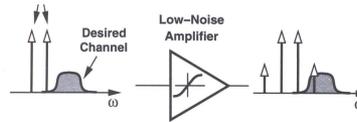
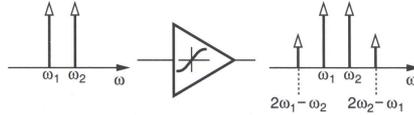
$$y(t) = \alpha_1 (A_1 \cos \omega_1 t + A_2 \cos \omega_2 t) + \alpha_2 (A_1 \cos \omega_1 t + A_2 \cos \omega_2 t)^2 + \alpha_3 (A_1 \cos \omega_1 t + A_2 \cos \omega_2 t)^3$$

$$\omega_1 \pm \omega_2 : \alpha_2 A_1 A_2 \cos(\omega_1 + \omega_2)t + \alpha_2 A_1 A_2 \cos(\omega_1 - \omega_2)t$$

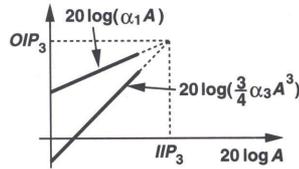
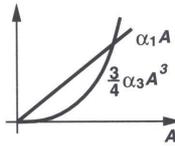
$$2\omega_1 \pm \omega_2 : \frac{3\alpha_3 A_1^2 A_2}{4} \cos(2\omega_1 + \omega_2)t + \frac{3\alpha_3 A_1^2 A_2}{4} \cos(2\omega_1 - \omega_2)t$$

$$2\omega_2 \pm \omega_1 : \frac{3\alpha_3 A_2^2 A_1}{4} \cos(2\omega_2 + \omega_1)t + \frac{3\alpha_3 A_2^2 A_1}{4} \cos(2\omega_2 - \omega_1)t$$

$$\omega = \omega_1, \omega_2 : \left(\alpha_1 A_1 + \frac{3}{4} \alpha_3 A_1^3 + \frac{3}{2} \alpha_3 A_1 A_2^2 \right) \cos \omega_1 t + \left(\alpha_1 A_2 + \frac{3}{4} \alpha_3 A_2^3 + \frac{3}{2} \alpha_3 A_2 A_1^2 \right) \cos \omega_2 t$$

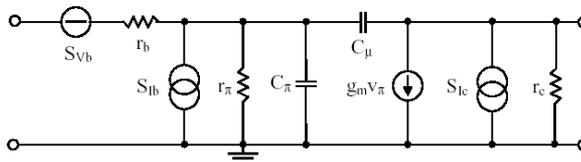


• Intercetta 3° Ordine: IP₃



Concetti di Base: Noise Figure (1)

• Sorgenti di Rumore



$$S_{v_b} = 4kTr_b \quad [V^2/Hz]$$

$$S_{i_b} = 2qI_B + \frac{A}{f} + \frac{B}{f^2} \quad [A^2/Hz]$$

$$S_{i_c} = 2qI_C \quad [A^2/Hz]$$

• Noise Figure (NF)

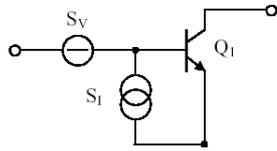
$$NF = 10 \log \frac{S_i / N_i}{S_u / N_u}$$

$$Ga = \frac{S_u}{S_i}$$

$$NF = 10 \log \frac{N_u}{Ga N_i}$$

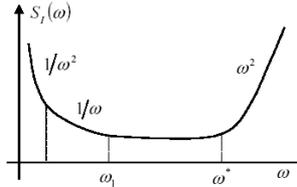
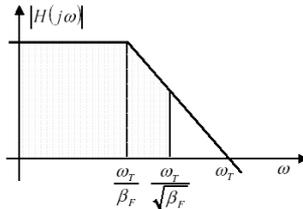
Concetti di Base: Noise Figure (2)

- Rumore riportato in ingresso



$$S_V = 4kT \cdot \left(r_b + \frac{1}{2g_m} \right)$$

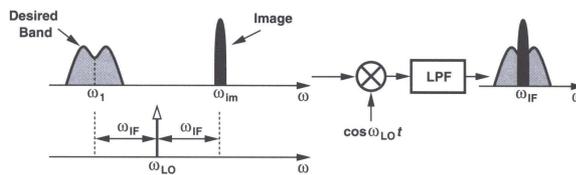
$$S_I = 2q \cdot [I_B + I_C \cdot (\omega / \omega_T)^2]$$



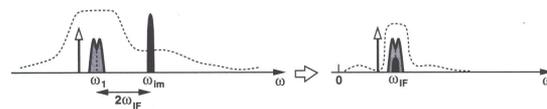
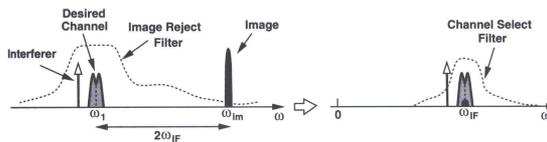
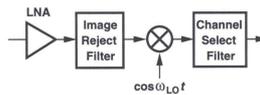
- NF per 2 stadi in cascata (formula di Friis)

$$NF_T = NF_1 + \frac{NF_2 - 1}{G_{a1}}$$

Architetture: Eterodina (1)

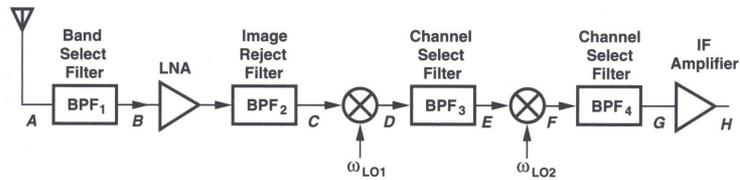


- Reiezione Immagine



Architetture: Eterodina (2)

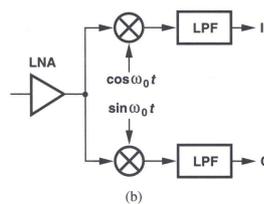
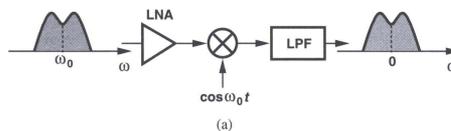
- Eterodina a Doppia Conversione



- ✓ Selectivity
- ✓ Sensitivity

Architetture: Omodina

- ✓ Assenza Segnale Immagine



- ❑ Mutua Interferenza: RF – Oscillatore Locale
- ❑ LO Leakage e I/Q Mismatch
- ❑ Rumore Flicker

Sommario

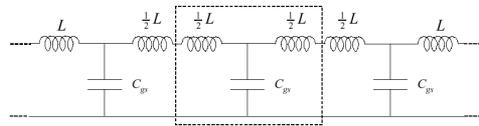
- ✓ Introduzione alla Progettazione RF
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Simulazioni Elettromagnetiche

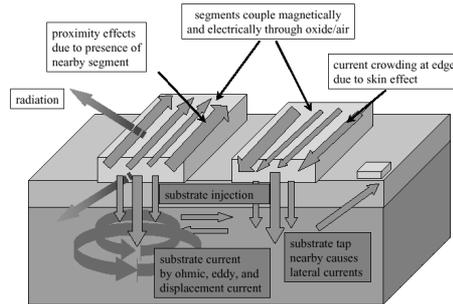
- Aspetti Generali
 - ❑ Approccio Elettromagnetico
 - ❑ Chip Packaging
- Simulatori
- ASITIC
 - ❑ Induttori
 - ❑ Trasformatori
- MicroWave Office
- HP HFSS (High Frequency Structures Simulator)

Approccio Elettromagnetico

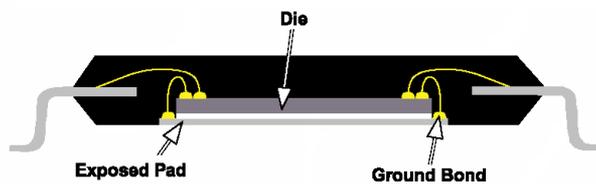
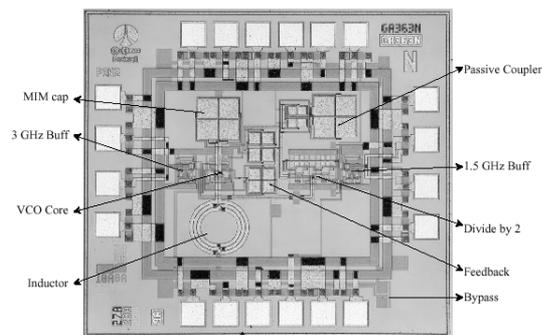
• Parametri Distribuiti



• Interazione Elettromagnetica

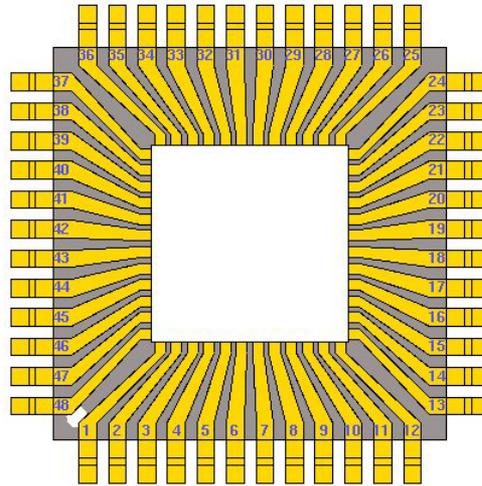


Chip Packaging (1)



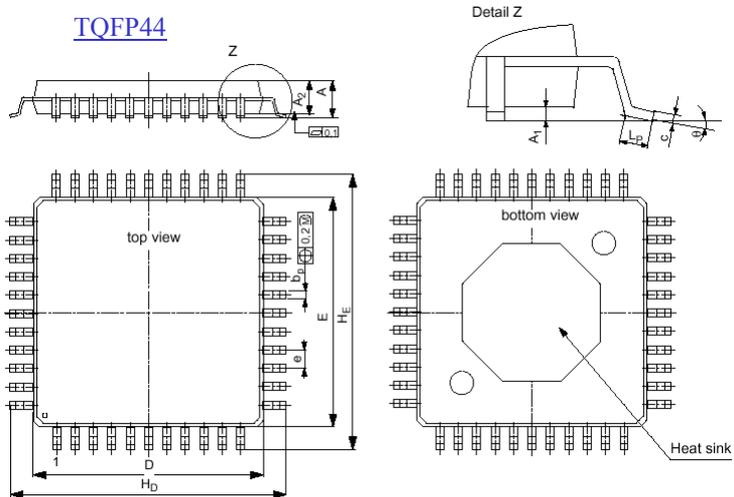
Chip Packaging (2)

TQFP48



Chip Packaging (3)

TQFP44



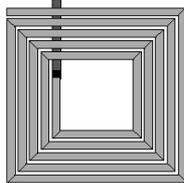
Simulatori Elettromagnetici

- Approccio Numerico
 - ❑ Time Domain (TD)
 - ❑ Frequency Domain (FD)
- Metodo Analitico
 - ❑ Momenti (FD)
 - ❑ Elementi Finiti (FD)
 - ❑ Differenze Finite (TD)
- Geometrie
 - ❑ 2D
 - ❑ 2D e 1/2 (ASITIC, MicroWave Office)
 - ❑ 3D (HP HFSS)

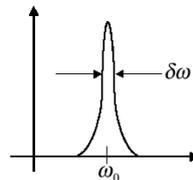
ASITIC: Flessibilità

- 4 Descrizioni

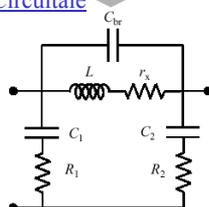
Geometrica



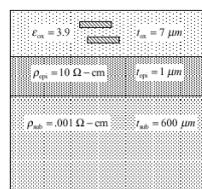
Elettrica



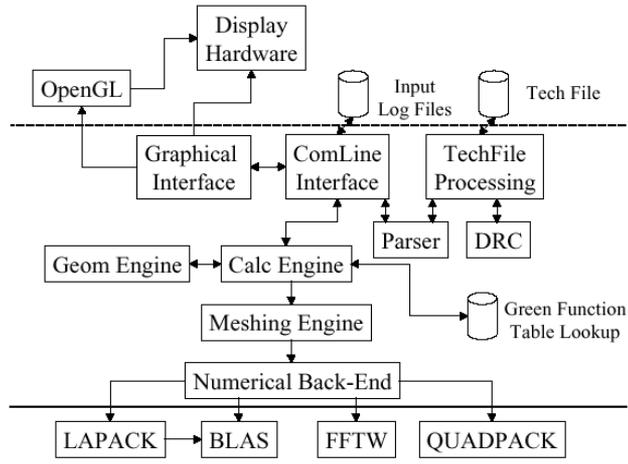
Circuitale



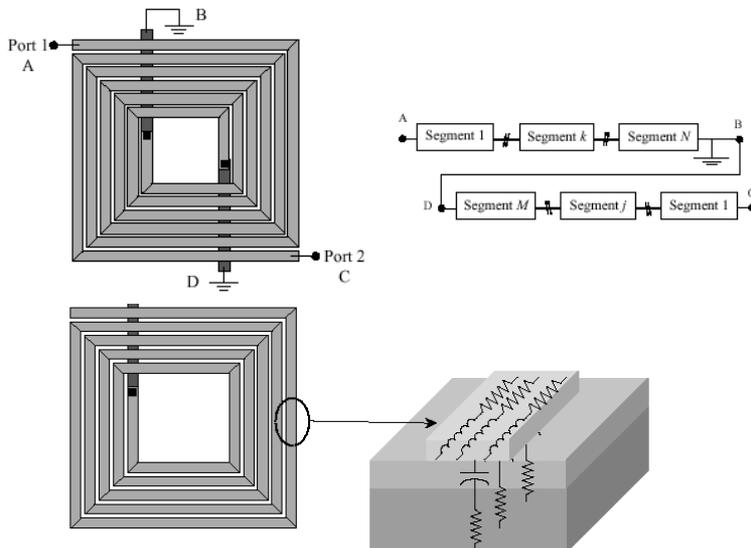
Fisica



ASITIC: Organizzazione

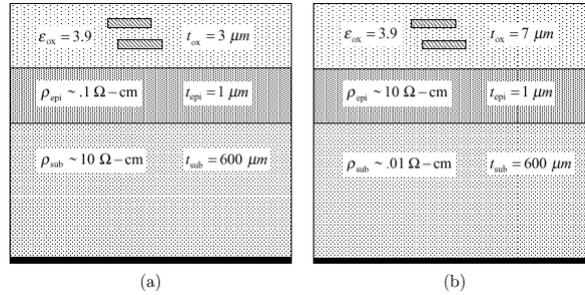


ASITIC: Segmentazione



ASITIC: Technology File

- File Testo e Descrizione Fisica



Bipolare

CMOS

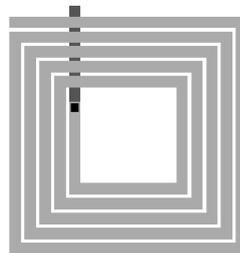
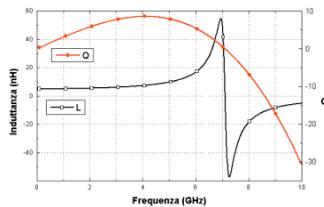
ASITIC: Spirals (Editing)

$$Q = \frac{\text{Im}(Z_L)}{\text{Re}(Z_L)}$$

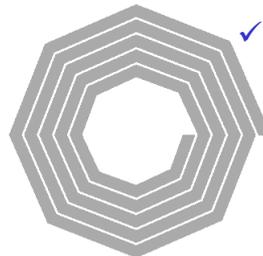
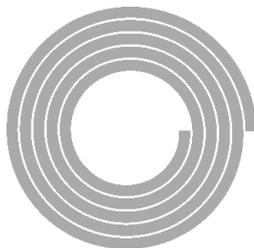
$$L = \text{Im}\left\{\frac{Z_L}{2\pi f}\right\}$$

$$R_L = \rho \frac{D}{TW}$$

$$\delta = \sqrt{\frac{1}{\pi f \mu \sigma}}$$

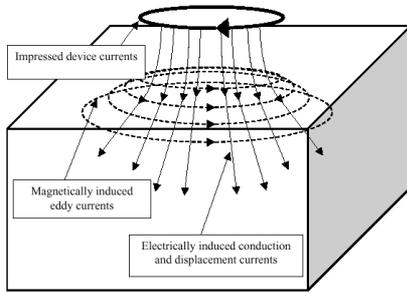


✓ Layout

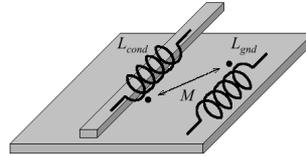


✓ High Q

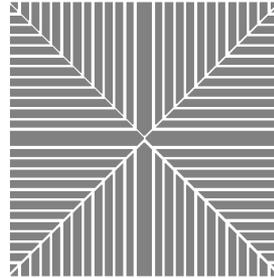
ASITIC: Eddy Current



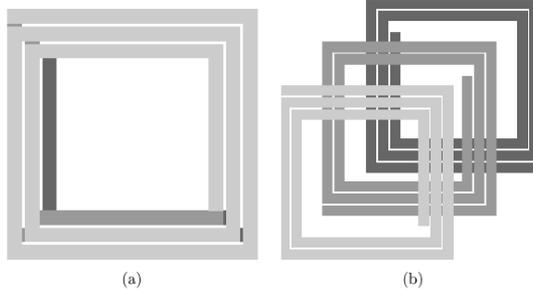
□ Legge di Lenz



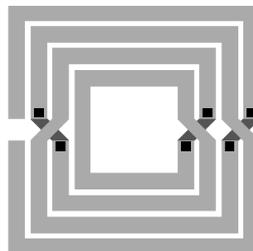
✓ Ground Pattern



ASITIC: Shunt and Symmetric Spirals

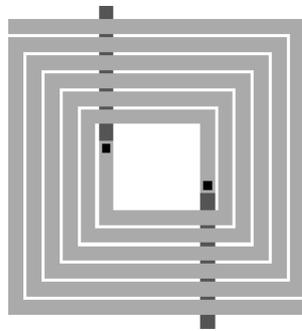


✓ High Q

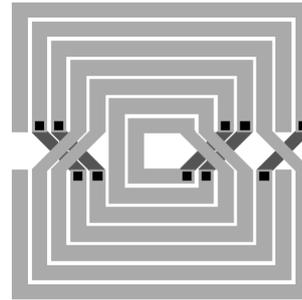


✓ Symmetry

ASITIC: Planar and Symmetric Transformers



✓ High Q



✓ Symmetry

ASITIC: Semplice Sessione

```
<chip>
chipx = 512 ; dimensions of the chip in x direction in microns
chipy = 512 ; dimensions of the chip in y direction
fftx = 256 ; x-fft size (must be a power of 2)
ffty = 256 ; y-fft size
TechFile = sample.tek ; the name of this file
TechPath = /home/niknejad/tektf ; the pathname of the data files
freq = .1

<layer> 0 ; Bulk Substrate

rho = .1 ; Resistivity: ohm-cm
t = 400 ; Thickness: microns
eps = 11.9 ; Permittivity: relative

<layer> 1 ; Epi Layer

rho = 15 ; ohm-cm
t = 1 ; microns
eps = 11.9 ; relative

<layer> 2 ; Oxide Layer

rho = 1e10 ; ohm-cm
t = 50 ; microns
eps = 4 ; relative

<via> 0 ; metal 1 to substrate

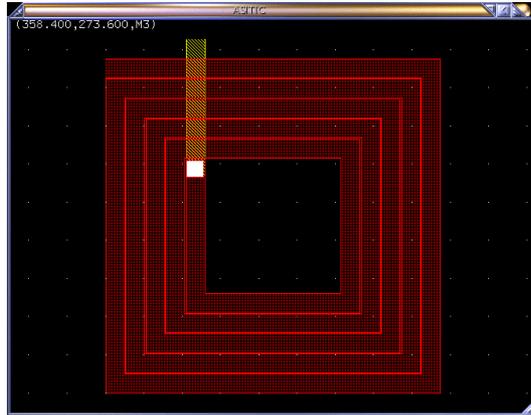
top = 1 ; via connects up to this metal layer
bottom = 0 ; via connects down to this metal layer
r = 5 ; resistance per via
width = .4 ; width of via
space = 1.3 ; minimum spacing between vias
overplot1 = .3 ; minimum dist to substrate metal
overplot2 = .3 ; minimum dist to metal 1
name = via0 ; name in ASITIC
color = purple ; color in ASITIC
```

✓ Segmento
di Techfile

Square Spiral (1)

```
tcsh> asitic -t sample1.tek
```

```
ASITIC> sq name=a:len=175:w=10:s=.5:n=5:xorg=200:yorg=200:metal=m3:exit=m2
```



Square Spiral (2)

```
ASITIC> ind a
```

```
Inductance of A = 4.13121 (nH)
```

```
ASITIC> res a
```

```
Resistance of A = 4.246441 (Ohms)
```

```
ASITIC> pix a 2
```

```
lambda = 37500.00, delta = 1.95
```

```
maxL = 1875.00, maxT = 1.56, maxW = 1.56
```

```
Performing Analysis at 2.00 GHz
```

```
Generating capacitance matrix (105x105)...
```

```
Generating inductance matrix (126x126)...
```

```
Inverting matrix.....
```

```
Ind Timing: tot = 1045, setup = 08, fill = 762
```

```
invert = 266, reduce = 05, eddy = 00
```

```
Calc Times (ms): total = 1378, cap = 309, ind = 1063, node = 05
```

```
Pi Model at f=2.00 GHz: Q = 7.02, 7.16, 8.20
```

```
L = 4.06 nH R = 5.29
```

```
Cs1= 104 fF Rs1= 638
```

```
Cs2= 97 fF Rs2= 710 f_res = 7.74GHz
```

Square Spiral (3)

```
ASITIC> sq name=halo:len=200:wid=200:w=20:n=1:xorg=180:yorg=180:s=10:metal=msub
ASITIC> mv halo 5 5
ASITIC> pix a 2 halo
```

```
lambda = 37500.00, delta = 1.95
```

```
maxL = 1875.00, maxT = 1.56, maxW = 1.56
```

```
Performing Analysis at 2.00 GHz
```

```
Generating capacitance matrix (141x141)...
```

```
Generating inductance matrix (126x126)..
```

```
Inverting matrix.....
```

```
Pi Model at f=2.00 GHz: Q = 7.85, 7.81, 8.20
```

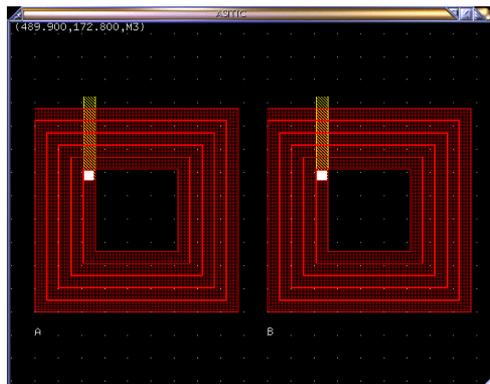
```
L = 3.98 nH R = 5.83
```

```
Cs1= 117 fF Rs1= 13.2
```

```
Cs2= 108 fF Rs2= 29.5 f_res = 7.39GHz
```

Coupling (1)

```
ASITIC> del halo
ASITIC> cp a b
ASITIC> mv a -100 0
ASITIC> mv b 100 0
ASITIC> friend a b
ASITIC> mv a -25 0
```



Coupling (2)

```
ASITIC> k a b

Coupling coefficient of A and B: k = -0.02748 and M = -0.11355
(nH).

ASITIC> k2 2 a b

lambda = 37500.00, delta = 1.95

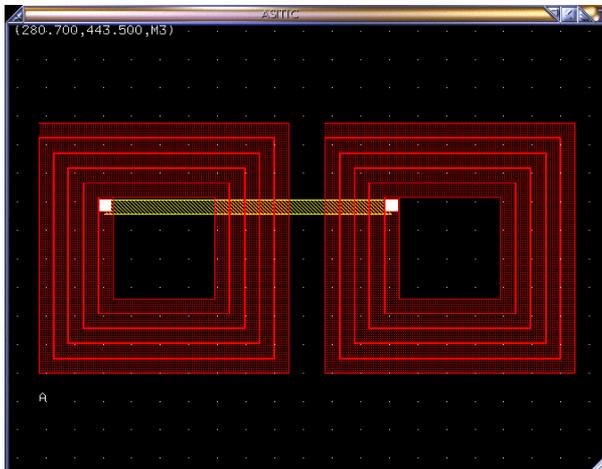
maxL = 1875.00, maxT = 1.56, maxW = 1.56
Generating inductance matrix (252x252)..
Inverting matrix.....
Ind Timing: tot = 4673, setup = 20, fill = 2117
invert = 2526, reduce = 33, eddy = 00

L(A,A) = 4.03648 nH R(A,A) = 6.120
L(A,B) = -0.11181 nH R(A,B) = -0.074
L(B,B) = 4.03624 nH R(B,B) = 6.127
```

Coupling (3)

$$Z = j\omega(L_1 + L_2 + 2M)$$

```
ASITIC> showdir
ASITIC> flip b
ASITIC> phase b -1
ASITIC> join a c b
ASITIC> ind a
Inductance of A = 8.80189 (nH)
```



Coupling (4)

```
ASITIC> pix a 2
```

```
lambda = 37500.00, delta = 1.95
```

```
maxL = 1875.00, maxT = 1.56, maxW = 1.56
```

```
Performing Analysis at 2.00 GHz
```

```
Generating capacitance matrix (205x205)...
```

```
Generating inductance matrix (246x246)..
```

```
Inverting matrix.....
```

```
Ind Timing: tot = 3964, setup = 02, fill = 1994
```

```
invert = 1963, reduce = 04, eddy = 00
```

```
Calc Times (ms): total = 6084, cap = 2099, ind = 3983, node = 02
```

```
Pi Model at f=2.00 GHz: Q = 4.90, 4.77, 7.36
```

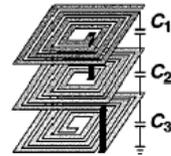
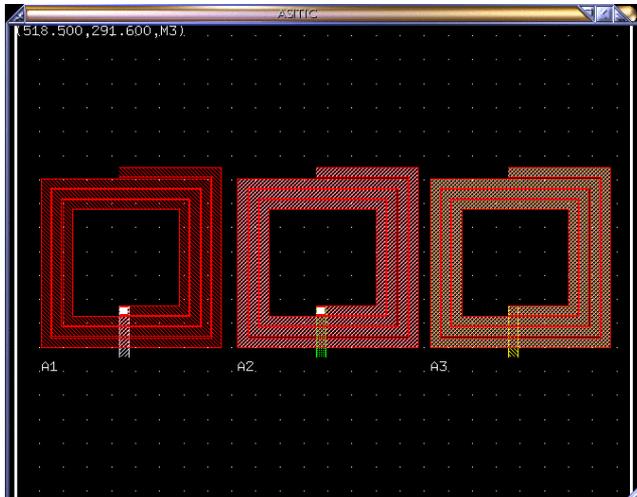
```
L = 8.64 nH R = 7.67
```

```
Cs1= 187 fF Rs1= 648
```

```
Cs2= 193 fF Rs2= 624 f_res = 3.96GHz
```

Multi-Layers Spiral (1)

```
ASITIC> sqsh name=a3:len=150:w=8:s=1:n=3.75:metal=m3:exit=m1:xorg=200:yorg=200:cbegin:cend:exit90
```



Multi-Layers Spiral (2)

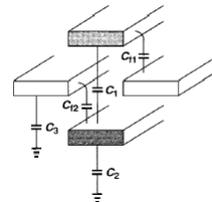
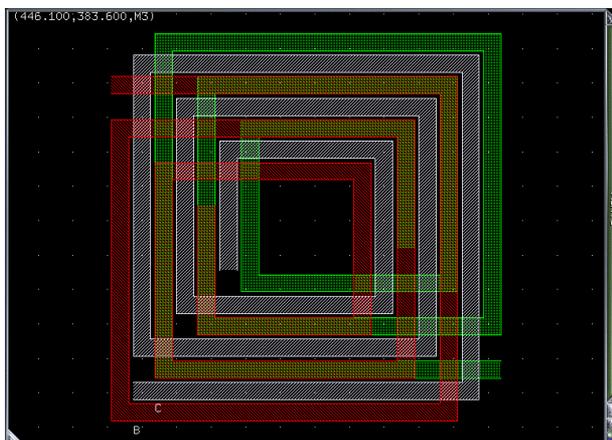
```
ASITIC> pix a3 3

lambda = 25000.00, delta = 1.84
maxL = 1250.00, maxT = 1.47, maxW = 1.47
Performing Analysis at 3.00 GHz
Generating capacitance matrix (184x184)...
Generating inductance matrix (230x230)..
Inverting matrix.....
Ind Timing: tot = 3006, setup = 32, fill = 2444
           invert = 495, reduce = 32, eddy = 00
Calc Times (ms): total = 5508, cap = 2502, ind = 3000, node = 05

Pi Model at f=3.00 GHz: Q = 7.33, 7.34, 8.59
L = 2.21 nH R = 4.04
Cs1= 89.2 fF Rs1= 665
Cs2= 89.7 fF Rs2= 683 f res = 11.34GHz
```

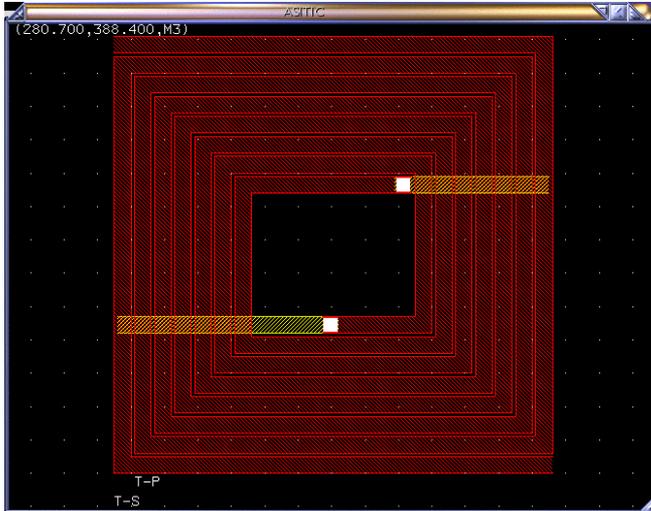
Multi-Layers Spiral (3)

```
ASITIC> del a1 a2 a3
ASITIC> sq name=s1:len=200:w=10:s=1:n=4:metal=m3:exit=m2:xorg=200:yorg=200:exit90
ASITIC> sqmm name=s2:len=200:w=10:s=1:n=4:metal=m3:exit=m2:xorg=200:yorg=200:exit90
```



Square Planar Transformer (1)

```
ASITIC> trans name=t:len=250:w=10:s=2:n=3.75
ASITIC> mv t-p 120 120
```



Square Transformer (2)

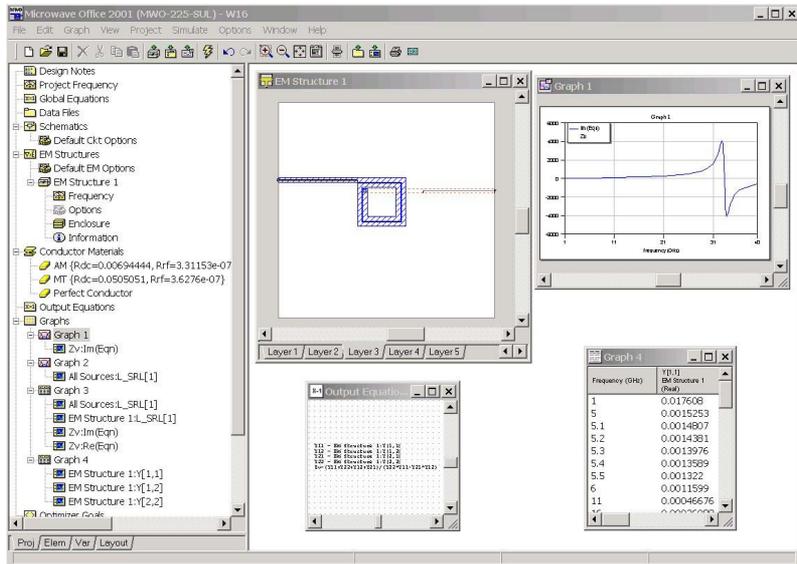
```
ASITIC> k2 1.2 t-s t-p
```

```
lambda = 62500.00, delta = 2.52
maxL = 3125.00, maxT = 2.01, maxW = 2.01
Generating inductance matrix (160x160)..
Inverting matrix.....
L(T-S,T-S) = 3.34111 nH      R(T-S,T-S) = 5.135
L(T-S,T-P) = 2.66867 nH    R(T-S,T-P) = 0.300
L(T-P,T-P) = 3.34187 nH    R(T-P,T-P) = 5.404
```

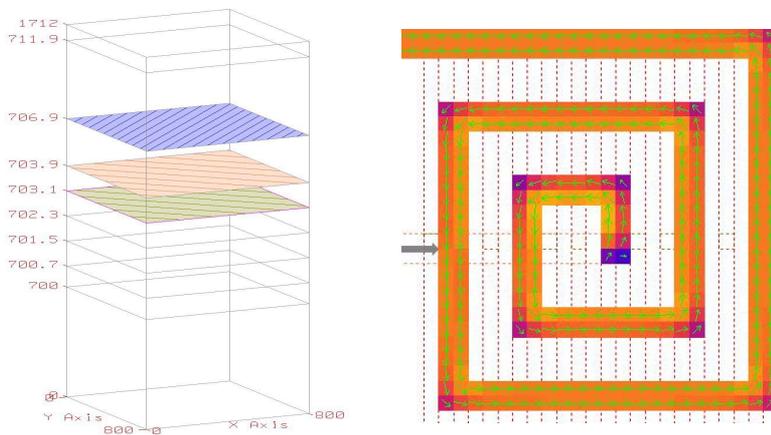
```
ASITIC> calctrans t-s t-p 2
```

```
lambda = 37500.00, delta = 1.95
maxL = 1875.00, maxT = 1.56, maxW = 1.56
Performing Analysis at 2.00 GHz
Generating capacitance matrix (160x160)...
Generating inductance matrix (192x192)..
Inverting matrix.....
Narrowband Model at f=2.00 GHz:
L1= 3.4 R1= 5.16 L2= 3.4 R2= 5.44 M= 2.73 (k= 0.805) Re(Z12) = 0.818
```

MicroWave Office: Finestra Principale



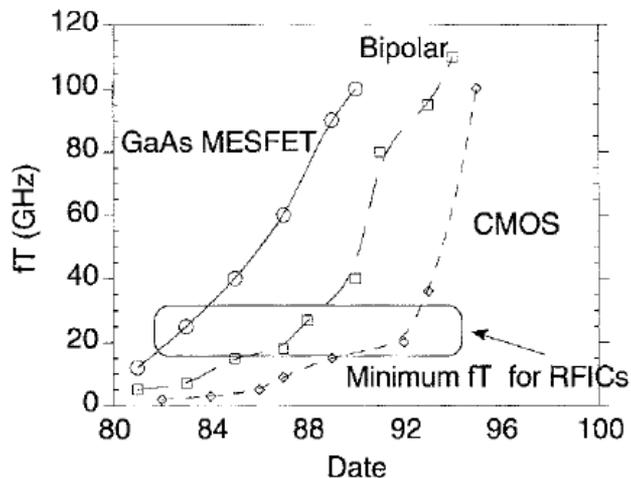
MicroWave Office: Grafica



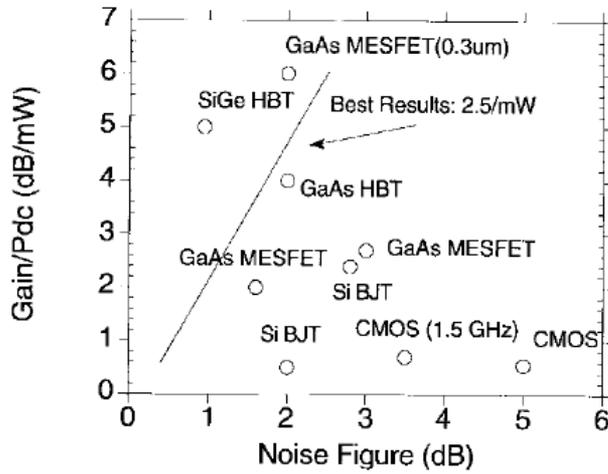
Sommario

- ✓ Introduzione alla Progettazione RF
- Progettazione di Front-end RF
 - ✓ Simulazioni Elettromagnetiche
 - Tecnologie e CAD Tools
 - Low Noise Amplifier (LNA)
 - Mixer
- Front-End Multi-Standard per WLAN 5-6 GHz
- Riepilogo e Conclusioni

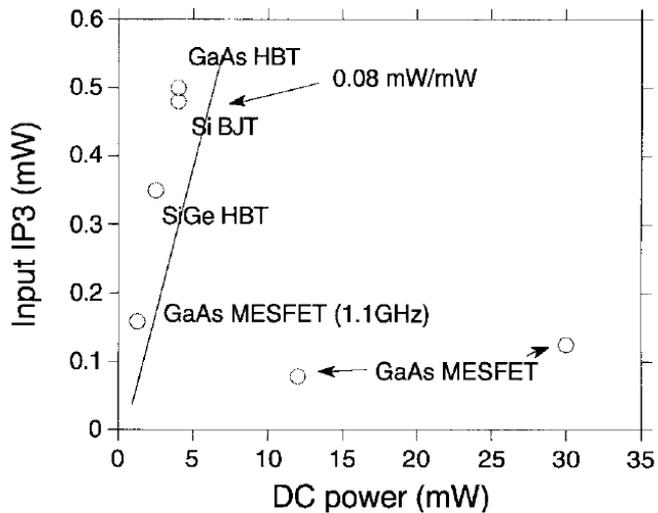
Tecnologie: Cut-Off Frequency (f_T)



Tecnologie: Gain-Noise



Tecnologie: IP3-Power



CAD Tools: Analisi Tradizionali

- DC
- AC (Lineare)
- Transitoria (Non Lineare)
- Sweep (Parametrica)
- Temperatura
- MonteCarlo
- Corner Analysis (Worst/Typical/Best Case)
- Sensitivity

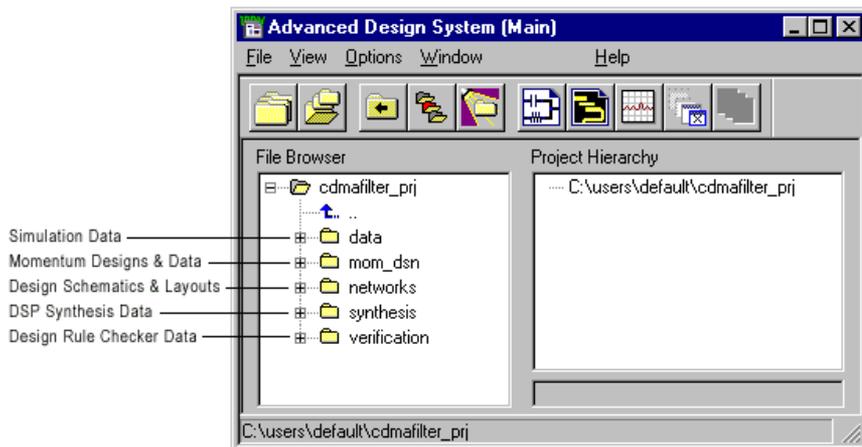
CAD Tools: Special Purpose

- Analisi Tradizionali
- S-Parameters (Lineare)
- Periodic Steady State (Non Lineare)
 - Harmonic Balance (ADS)
 - Shooting (SpectreRF)
- Ottimizzazione
- Piattaforme Software: Design Entry to Layout

Principali Tool

- ADS (Advanced Design Systems) - Agilent Technologies
 - Finestra principale
 - Analisi
 - Grafica
- Cadence Design Framework – Cadence
 - Finestra Principale
 - Grafica
 - Simulatore Analog Artist (SprectreRF)
 - Analisi

ADS: Finestra Principale



ADS: Analisi

NOMINAL OPTIMIZATION

Optim
 Optim1
 OptimType=Genetic
 ErrorForm=L2
 MaxIters=
 P=2
 DesiredError=0.0
 StatusLevel=4
 SetBestValues=yes
 Seed=
 SaveSols=no
 SaveOptimVars=no
 SaveGoals=no
 GoalName[1]="OptimGoal1"
 GoalName[2]="OptimGoal2"
 GoalName[3]=

GOAL

Goal
 OptimGoal1
 Expr="dB(S(1,1))"
 SimInstanceName="SP1"
 Min=-100
 Max=20
 Weight=
 RangeVar[1]=
 RangeMin[1]=
 RangeMax[1]=

GOAL

Goal
 OptimGoal2
 Expr="dB(S(2,1))"
 SimInstanceName="SP1"
 Min=25
 Max=25.5
 Weight=
 RangeVar[1]=
 RangeMin[1]=
 RangeMax[1]=

HARMONIC BALANCE

HarmonicBalance
 HB1
 Freq[1]=50 MHz
 Order[1]=3
 Tran
 Tran1
 StopTime=5000 nsec
 MaxTimeStep=100 nsec

TRANSIENT

S PARAMETERS

S_Param
 SP1
 Start=1.0 MHz
 Stop=210 MHz
 Step=1.0 MHz

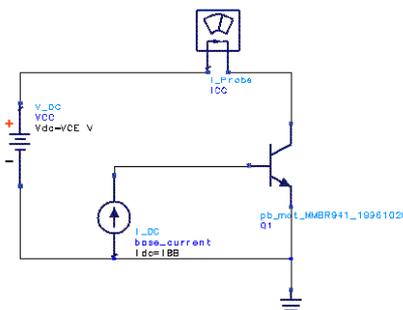
AC

AC
 AC1
 Start=1.0 MHz
 Stop=210 MHz
 Step=1 MHz

DC

DC
 DC1

ADS: Grafica



SIMULATIONS

DC

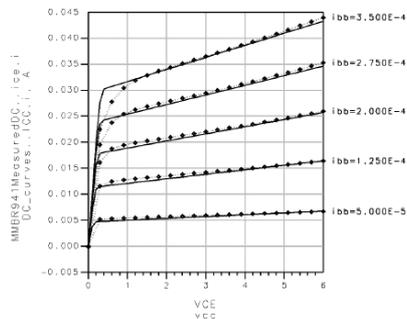
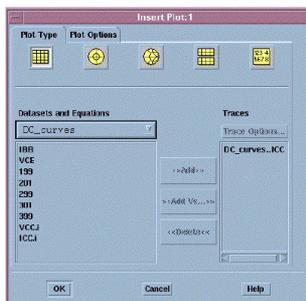
DC
 DC1
 SweepVar="VCE"
 Start=0 V
 Stop=8 V
 Step=0.1 V

PARAMETER SWEEP

ParameterSweep
 Sweep1
 SweepVar="Ibb"
 SimulationName[1]="DC1"
 SimulationName[2]=
 SimulationName[3]=
 SimulationName[4]=
 SimulationName[5]=
 Start=50 uA
 Stop=350 uA
 Step=75 uA

VARIABLES

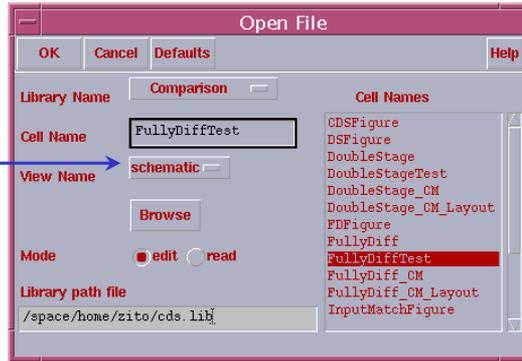
VAR Ibb
 VAR VCE=VY
 IBB=DA



Cadence: Finestra Principale

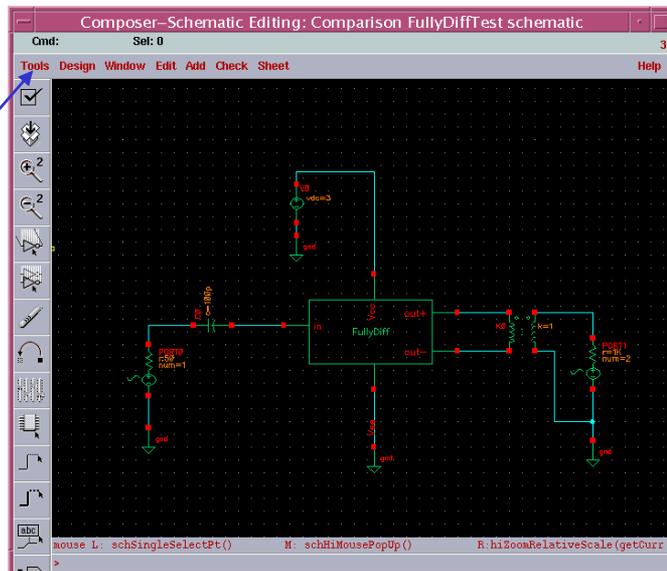


schematic
symbol
layout
extracted



Cadence: Grafica

Analog Artist



Simulatore: Analog Artist (Spectre RF)

The screenshot shows the main interface of the Analog Artist Simulation software. The title bar reads "Analog Artist Simulation (4)". The status bar indicates "Status: Ready" and "T=27 C. Simulator: spectre 9". The main window is divided into several sections:

- Design:** Includes a table for Library Comparison and Design Variables.
- Analyses:** A table listing analysis types and their parameters.
- Outputs:** A table listing output names and their settings.

Surrounding the main window are several callout boxes pointing to specific menu items:

- Design ...**: Simulator/Directory/Host ..., Temperature ..., Model Path ..., Environment ..., Stimulus, Simulation Files
- Choose ...**: Delete, Enable, Disable
- Edit ...**: Delete, Find, Copy From Cellview, Copy To Cellview
- Setup ...**: Delete, To Be Saved, To Be Marched, To Be Plotted, Save All ...
- Run**: Stop, Options, Netlist, Command Type-In ..., Output Log ..., Convergence Aids
- Plot Outputs**: Direct Plot, Print, Annotate, Save ..., Select ..., Plotting Options ...
- Parametric Analysis ...**: Monte Carlo ..., Statistics ..., Optimization ..., Calculator ..., Results Browser ..., Waveform ...
- Schematic Window ...**: Save State ..., Load State ..., Options ..., Reset, Quit

Cadence: Analisi

The screenshot shows the "Choosing Analyses" dialog box for the Analog Artist Simulation. The dialog has buttons for "OK", "Cancel", "Defaults", "Apply", and "Help".

Analysis section:

- tran
- dc
- ac
- noise
- xf
- sens
- sp
- pdisto
- pss
- pac
- pnoise
- pxf

AC Analysis section:

Sweep Variable

- Frequency
- Design Variable
- Temperature
- Component Parameter
- Model Parameter

Sweep Range

- Start-Stop
- Center-Span

Start: Stop:

Sweep Type

Automatic

Add Specific Points

Enabled Options...

Sommario

- ✓ Introduzione alla Progettazione RF
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 - ☐ Mixer
- Front-End Multi-Standard per WLAN 5-6 GHz
- Riepilogo e Conclusioni

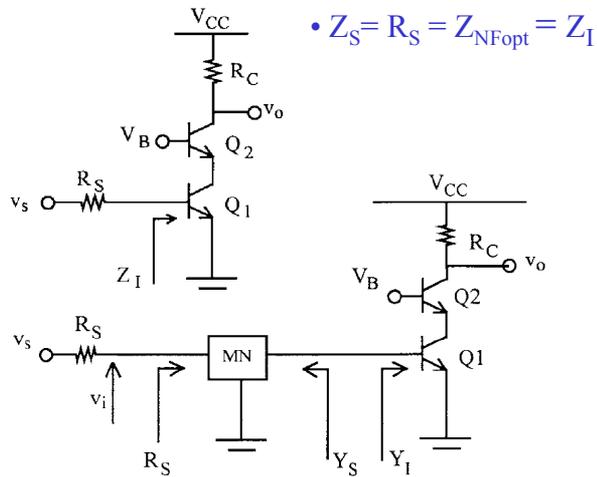
Low Noise Amplifier (LNA)

- Input Matching
- Noise Figure (NF)
- Scelta della Configurazione
- Guadagno
- Linearità
 - ☐ Punto di Compressione (CP1dB)
 - ☐ Intercetta del 3° Ordine (IP3)
- Stabilità
- Topologia Base Coupled Differential (BCD)
- LNA Selettivo Integrato: Boot-Strapped Inductor

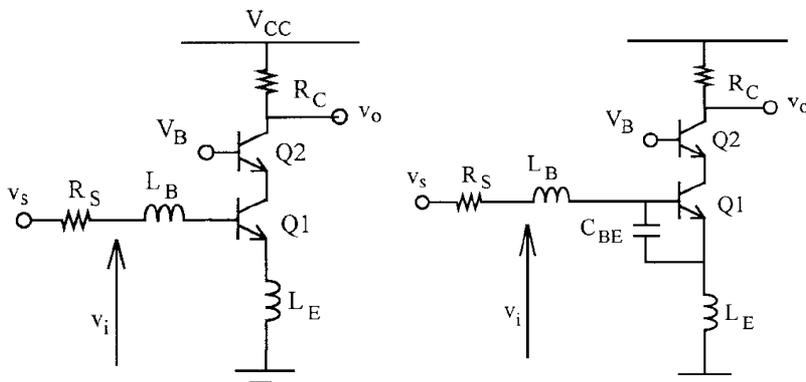
• Parametri Tipici

<i>NF</i>	2 dB
<i>IIP₃</i>	-10 dBm
Gain	15 dB
Input and Output Impedance	50 Ω
Input and Output Return Loss	-15 dB
Reverse Isolation	20 dB
Stability Factor	> 1

Input Matching



Input Matching e Noise Figure



$$Z_{in} = r_b + \frac{g_m L_e}{C_\pi} + L_e s + \frac{1}{C_\pi s}$$

Input Matching e NF: Flusso di Progetto

- Test NF Minima

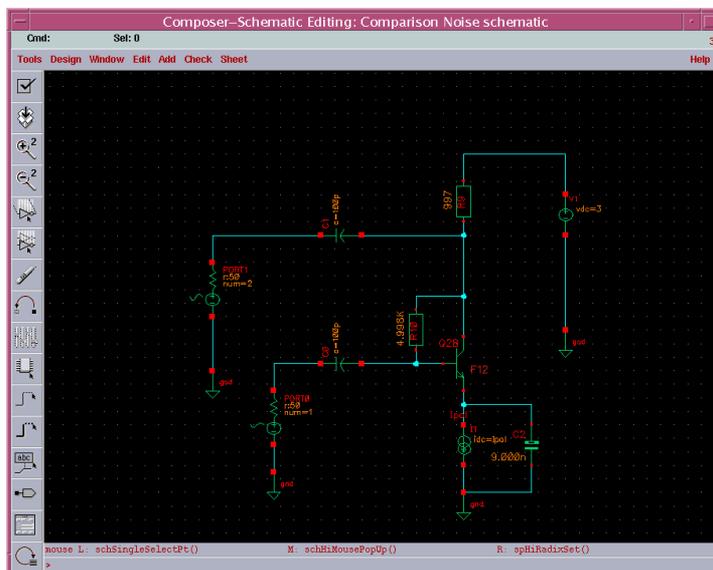


- Scelta del Numero di Transistori (R_{ON} , Area, PD_{MAX})



- Calcolo della Induttanza di Degenerazione

Input Matching e NF: NF_{Min} (1)



Input Matching e NF: NF_{Min} (2)

Analog Artist Simulation (4) T=27 C Simulator: spectre 9

Status: Ready

Session Setup Analyses Variables Outputs Simulation Results Tools Help

Design

Library	Comparison	#	Type	Arguments.....	Enable
Cell	Noise	1	sp	100u 6m Auto.. Star..	yes
View	schematic	2	noise	1G 3G 100 Line..	yes
		3	dc	t	yes

Design Variables

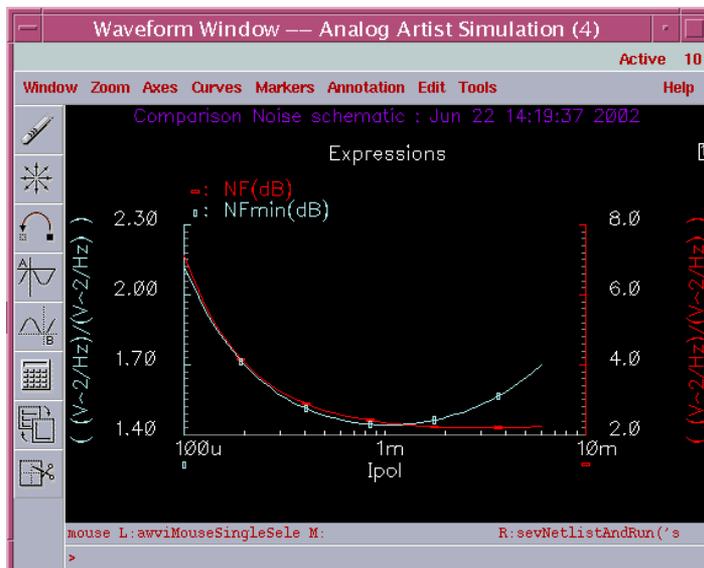
#	Name	Value
1	Ipol	1.8m
2	vin	1
3	RF	2.44G

Analyses

#	Name/Signal/Expr	Value	Plot	Save	March
1	NFmin(dB)	wave	yes		
2	NF (dB)	wave	yes		

> Results in /space/home/zito/simulation/Noise/spectre/schematic

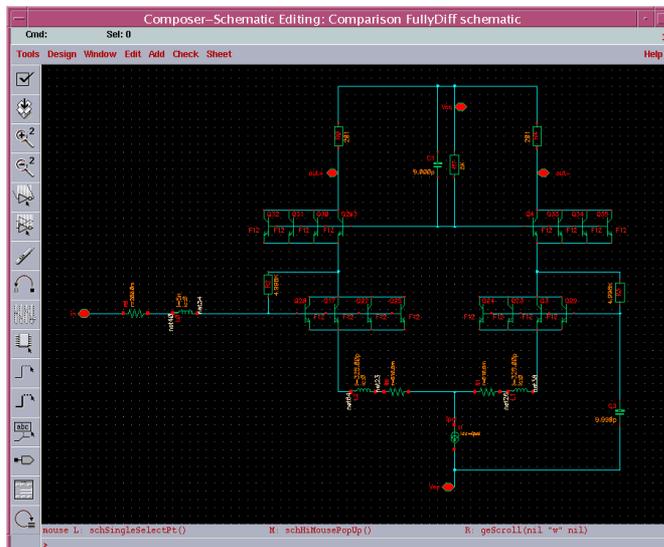
Input Matching e NF: NF_{Min} (3)



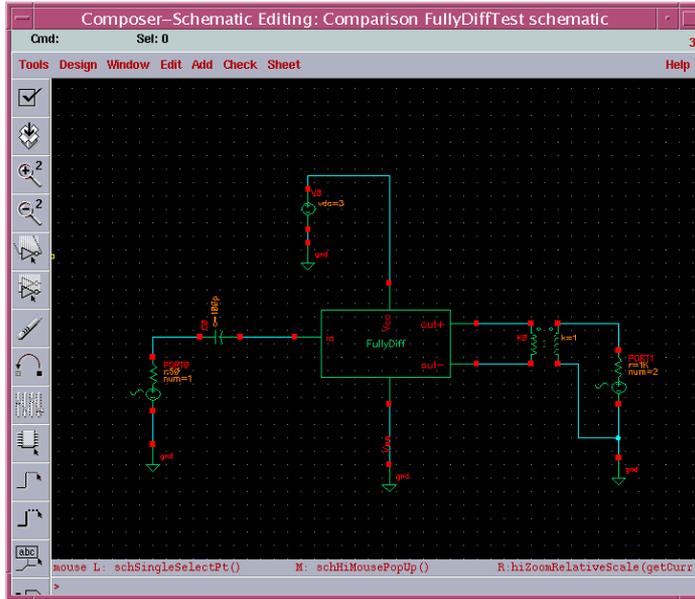
Scelta della Configurazione

- Noise Figure
- Guadagno
- Limite Superiore di Banda
- Differenziale
 - ✓ Linearità, Immunità ai Disturbi
 - ☐ Consumo di Potenza
- Input Matching
- ✓ Cascode: Best Trade-Off

Scelta della Configurazione: Cascode Differenziale



Schema di Simulazione



Input Matching: Z_{in} (1)

Analog Artist Simulation (5) T=27 C Simulator: spectre 12

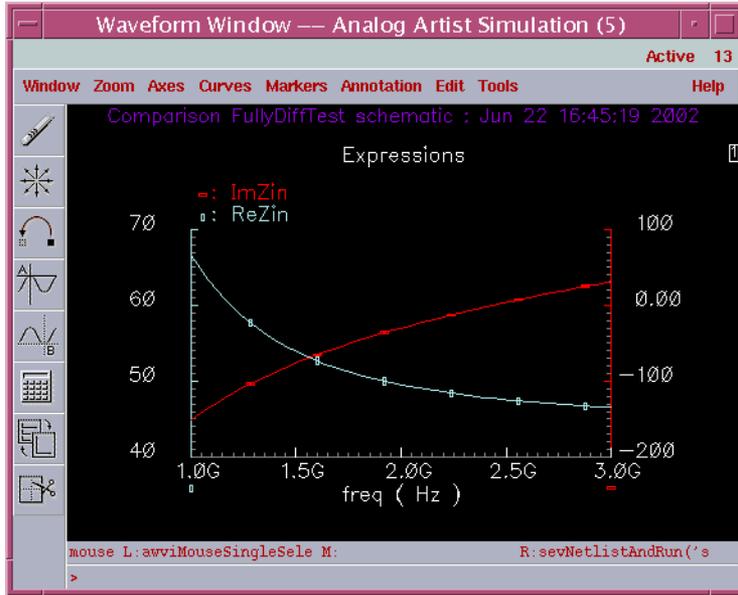
Status: Ready Help

Session Setup Analyses Variables Outputs Simulation Results Tools

Design		Analyses			
Library	Cell	#	Type	Arguments.....	Enable
Comparison	FullyDiffTest	1	ac	10 30 Auto.. Star..	yes

Design Variables			Outputs			
#	Name	Value	#	Name/Signal/Expr	Value	Plot Save March
1	Ipol	6.6m	1	ReZin		yes
2	vin	1m	2	ImZin		yes
3	RF	2.44G				

Input Matching: Z_{in} (2)



Input Matching: NF (1)

Analog Artist Simulation (5) T=27 C Simulator: spectre 12

Status: Ready

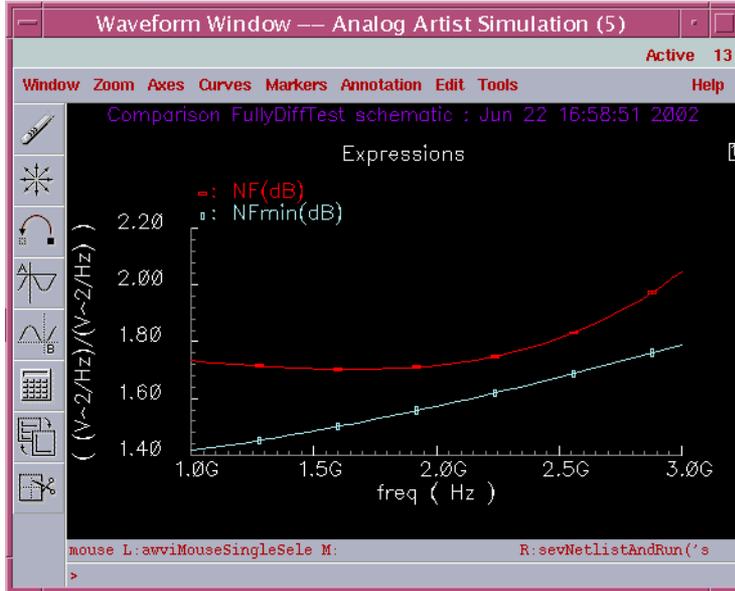
Session Setup Analyses Variables Outputs Simulation Results Tools Help

Design		Analyses			
Library	Cell	#	Type	Arguments.....	Enable
Comparison	FullyDiffTest	1	sp	1G 3G	Auto.. Star.. yes
		2	noise	1G 3G	100 Line.. yes
		3	ac	1G 3G	Auto.. Star.. yes

Design Variables			Outputs		
#	Name	Value	#	Name/Signal/Expr	Value Plot Save March
1	vin	1	1	NFmin (dB)	yes
2	RF	2.44G	2	NF (dB)	yes
3	Ipol	6.6m			

> Results in /space/home/zito/simulation/FullyDiffTest/spectre/schematic

Input Matching: NF (2)



Guadagno: A_V (1)

Analog Artist Simulation (5)

Status: Ready T=27 C Simulator: spectre 12

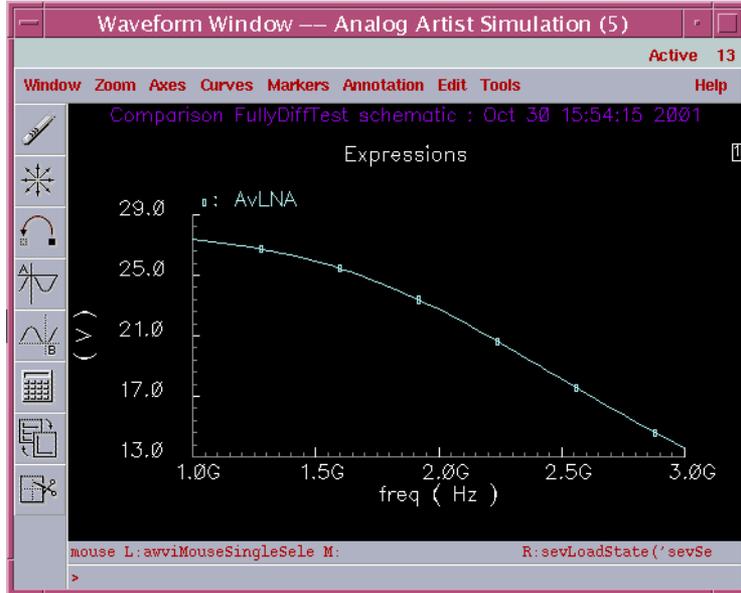
Session Setup Analyses Variables Outputs Simulation Results Tools Help

Design		Analyses			
Library	Cell	#	Type	Arguments.....	Enable
Comparison	FullyDiffTest	1	dc	t	yes
		2	ac	1G 3G Auto.. Star..	yes

Design Variables			Outputs			
#	Name	Value	#	Name/Signal/Expr	Value	Plot Save March
1	Ipol	6.6m	1	AvLNA		yes
2	vin	1				
3	RF	2.44G				

> Results in /space/home/zito/simulation/FullyDiffTest/spectre/schematic

Guadagno: $A_V(2)$



Linearità: CP_{1dB} (1)

✓ Input Port

Edit Object Properties

Apply To: only current Instance

Show: system user CDF

Property: Library Name: analog11M, Off Name: psd1, View Name: sysbcd, Instance Name: port1

User Property: Invsigore: TRUE

CDF Parameter:

Property	Value	Display
Frequency name	Hz	off
Second frequency name		off
Noise file name		off
Number of noise/freq pairs	5	off
Resistance	50 Ohm	off
Port number	1	off
DC voltage		off
Source type	sin	off
Delay time		off
Sine DC level		off
Amplitude		off
Amplitude (dBm)	Pr	off
Initial phase for Sinusoid		off
Frequency	Pr Hz	off
Amplitude 2		off
Amplitude 2 (dBm)		off
Initial phase for Sinusoid 2		off
Frequency 2		off
FM modulation index		off
FM modulation frequency		off
AM modulation index		off

✓ PSS Analysis

Choosing Analyses --- Analog Artist Simulation L

Periodic Steady State Analysis

#	Base	Edge	Value	Signal	Sec14
3	Hz	Hz	2.440	Moderate	Port05

Accuracy defaults (represent): conservative Moderate Sound

Additional Time for Stabilization (static):

Save Initial Transient Results (saveinit): no yes

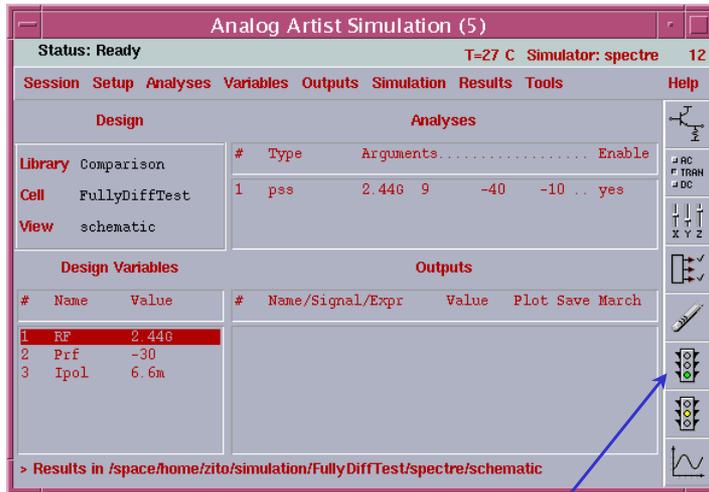
Disabler:

Sweep: Variable Variable Name: PrZ

Sweep Range: Start: -40 Stop: -10

Sweep Type: Linear Logarithmic

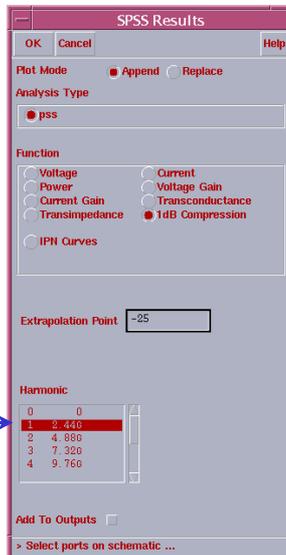
Linearità: CP_{1dB} (2)



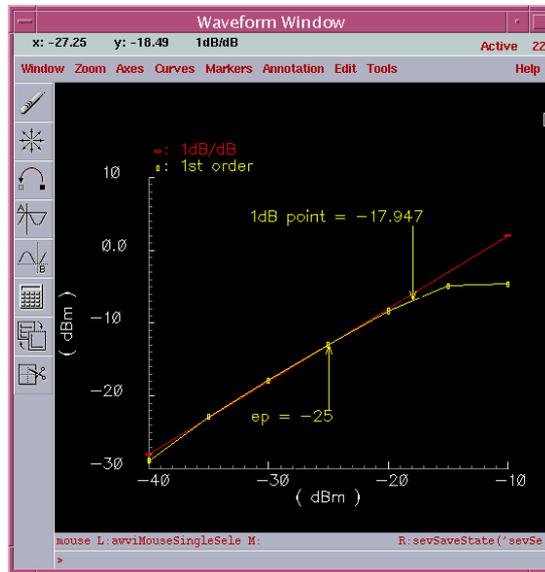
Run Simulation

Linearità: CP_{1dB} (3)

1^a Armonica →



Linearità: CP_{1dB} (4)



Linearità: IP₃ (1)

✓ Input Port

Edit Object Properties

Apply To: only current Instance

Show: system user CDF

Property: Value Display

Library Name: seaLogLib off

Cell Name: port1 off

View Name: symbol off

Instance Name: Port1 off

User Property: Master Value Local Value Display

Ignore: 250E off

CDF Parameter: Value Display

Frequency name: f0 off

Second frequency name: f0 off

Noise file name: off

Number of noise/freq pairs: 0 off

Resistance: 50 Ohm off

Port number: 1 off

DC voltage: off

Source type: sine off

Delay time: off

Sine DC level: off

Amplitude: 1V off

Amplitude (dBm): 0 off

Initial phase for sinusoid: off

Frequency: 10 off

Amplitude 2: off

Amplitude 2 (dBm): off

Initial phase for sinusoid 2: off

Frequency 2: off

FM modulation index: off

FM modulation frequency: off

AM modulation index: off

✓ PSS Analysis

Choosing Analyses — Analog Artist Simulation

Periodic Steady State Analysis

Fundamental Tones

#	Row	Expr	Value	Signal	SrcId
1	f0	f0	2.4320	Moderate	P0050
2	f0	f0	2.4450	Moderate	P0050

RF: RF 2.4320 Moderate P0050

Clear/Add Delete Update From Schematic

Real Frequency: 100 Auto Calculate

Deal Period: off

Output harmonics: Number of harmonics: 100

Accuracy (defaults represent): conservative moderate sound

Additional Time for Stabilization (secs): 10

Save Initial Transient Results (saveinit): no yes

Oscillator: off

Sweep: Variable Frequency Variable? no yes

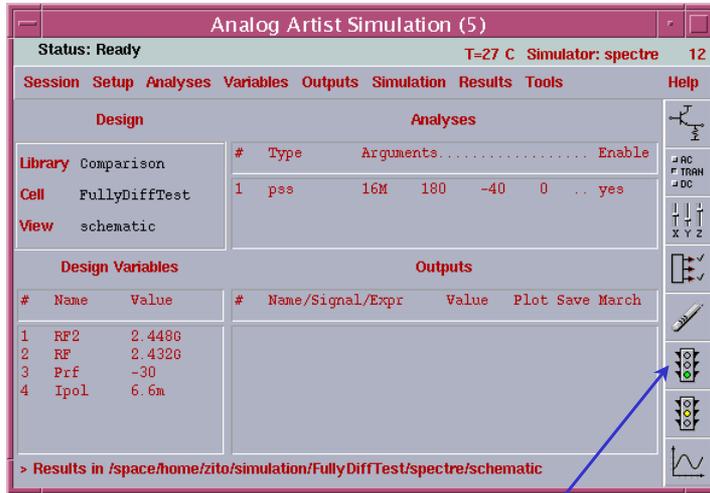
Variable: Variable Name: f0

Select Design Variable

Sweep Range: Start-Stop Center-Span Start: -10 Step: 1

Sweep Type: Linear Step Size Logarithmic Number of Steps: 10

Linearità: IP₃ (2)



Run Simulation

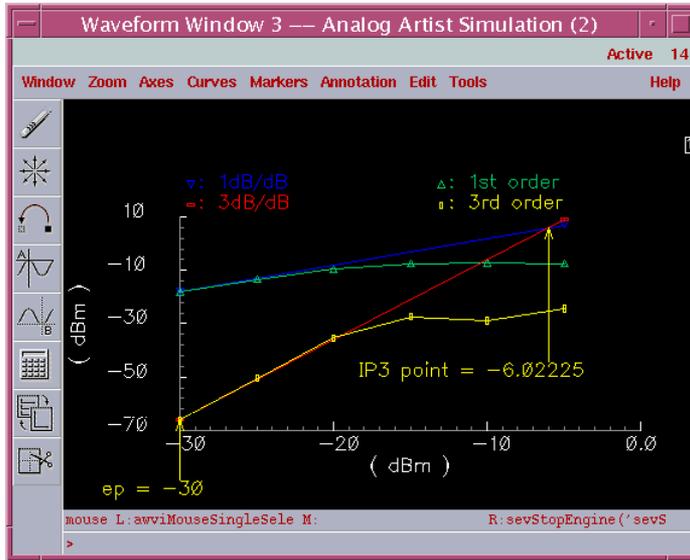
Linearità: IP₃ (3)



Armonica da Intermodulazione

1ª Armonica

Linearità: IP_3 (4)



Stabilità: Analisi Transitoria (1)

Analog Artist Simulation (3)

Status: Ready T=27 C Simulator: spectre 16

Session Setup Analyses Variables Outputs Simulation Results Tools Help

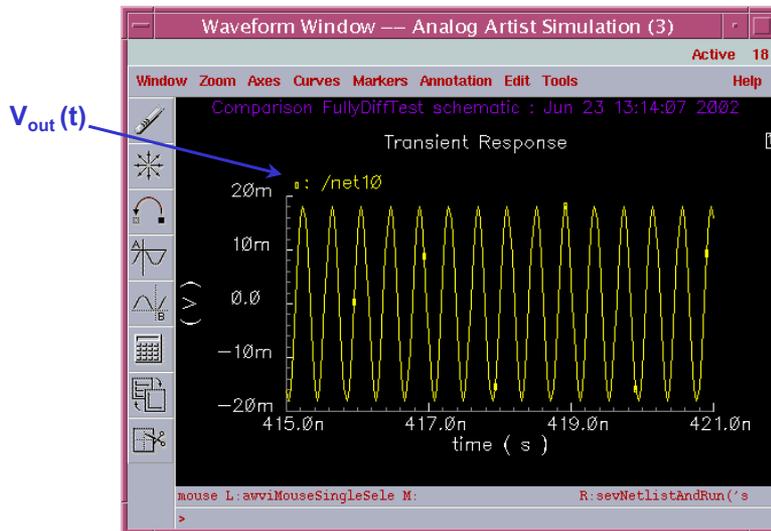
Design		Analyses			
Library	Comparison	#	Type	Arguments.....	Enable
Cell	FullyDiffTest	1	tran	0 500n mode..	yes
View	schematic				

Design Variables			Outputs			
#	Name	Value	#	Name/Signal/Expr	Value	Plot Save March
1	RF	2.44G	1	net10		yes allv no
2	Ipo1	6.6m				

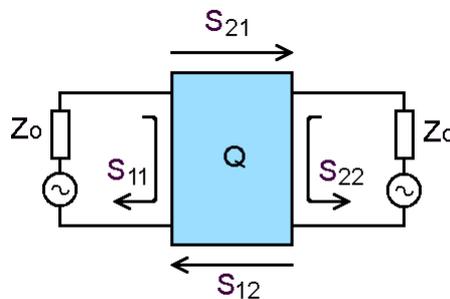
Run Simulation

$V_{out}(t)$

Stabilità: Analisi Transitoria (2)



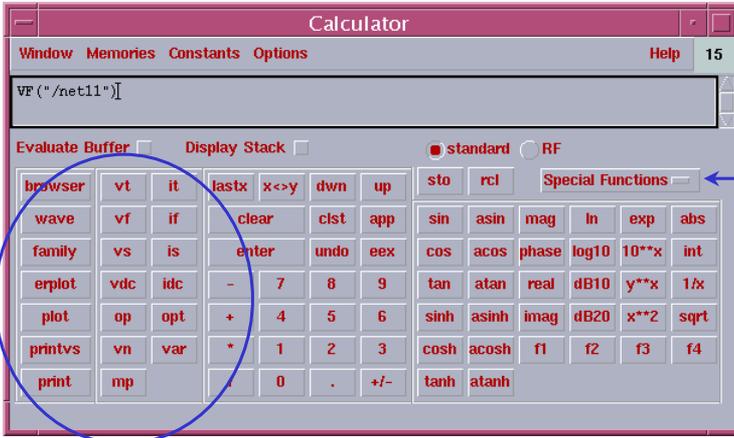
Stabilità: Incondizionata



$$K = \frac{1 + |\Delta|^2 - |S_{11}|^2 - |S_{22}|^2}{2|S_{21}||S_{12}|}$$

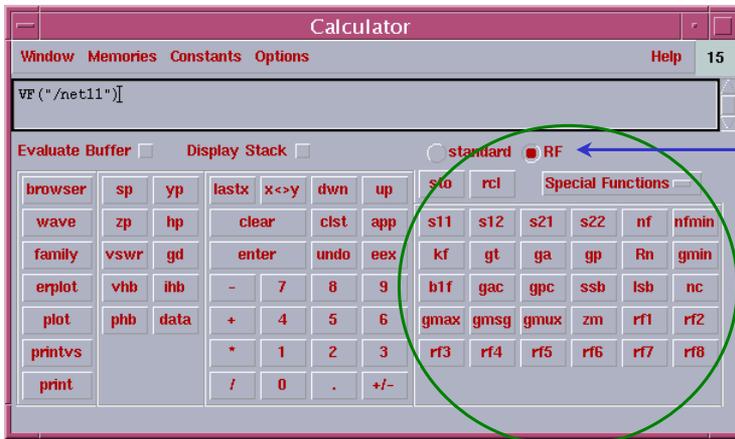
$K > 1, |\Delta| < 1 \Rightarrow$ Incondizionatamente Stabile

Analog Artist: Calculator (1)



- Bandwidth
- DFT
- Overshoot
- Gain Margin
- Xmax
- Ymax
- ...
- ...

Analog Artist: Calculator (2)



RF

Riepilogo

- ✓ Introduzione alla Progettazione RF
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 - ☐ Topologia BCD
 - ☐ LNA Selettivo Integrato
 - ☐ Mixer
- Front-End Multi-Standard per WLAN 5-6 GHz
- Riepilogo e Conclusioni