Computer Aided Design & Simulation of Electrical Circuits and Systems

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Motivation

Bridge from design specifications of electric circuits with a set of desired responses, to real circuits with nearly the same desired performance.

Our Tool Set

- DC analysis
- AC frequency response
- Time and transient analysis
- Nonlinear analysis
- Synthesis vs. optimization
- Modeling & Data Analysis
- Thermal Design
- System Analysis
- Electromagnetics and interconnects
- Our capabilities span DC… Audio… RF… Microwave
The Design Process: Part I

- Design Specifications
- Initial Design
- Synthesis Methods

HARDWARE Steps:
- Breadboard...Measure...Modify...
- Prototype...Fabricate...Test...Tune

To Software Iterations

Active Filters
- Truth Tables
- Filter Prototype Tables
- Smith Chart
- MATLAB
- MATHCAD
- $Q^2 + 1$
- Circuit Mapping
- Real Freq. Tech.
- Karnaugh Maps
- Filter Syn.
Software Iterations: Part II

- CKT Description
- Analysis
- Sensitivity Analysis
- Optimization
- Models
- Yield Analysis
- CAD Layout
- Fabrication
- Design Rules
Software Iterations: Feedback from EM!

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This diagram illustrates the iterative process involving CKT description, analysis, sensitivity analysis, optimization, models, yield analysis, CAD layout, and fabrication. Each step is interconnected, highlighting the feedback loop between design and analysis.
Nodal, Linear, Nonlinear, AC, Time Response

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- Optimization
- Yield Analysis
- Fabrication
- CAD Layout
- Design Rules
Circuit Models are a Critical Element

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Optimization... Intelligent Tuning

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Design Feedback from EM is Essential

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Real circuits and Models

R, L, C are merged elements

Interconnects are significant

The datum node (ground) is not apparent

Wire… a complex element!
The Influence of Interconnects and Models

An ideal low pass filter, from synthesis element values are $-j\Omega_0$, $+2j\Omega_0$, $-j\Omega_0$ with assigned cutoff frequency.

Identical datum nodes (ground)

Our filter constructed on pc material with surface mount, ground (datum) via’s, and input out pads.

Simulation conducted in Microwave Office
The results of subtle differences

Use of actual LC models
Pad capacity affects
Junction element discontinuities
Via inductance, datum node upset
Incomplete pc etch! (!@#$)
A Live Simulation Utilizing LT Spice

Parametric Sweep… Filters
Non-Linear Relaxation and Sinusoidal Oscillators

First, consider a non linear network consisting of linear elements, the essential elements of an oscillator.
Nonlinear Network from Linear Elements

Oscillator Key Elements

- Timing function
  \[ i(t) = C \frac{dV}{dt} \rightarrow \frac{\Delta V}{\Delta t} = \frac{i(t)}{C} \]

- Feedback
- Threshold detection
- Limiting
- Delay

Sweep Rate ~ 3.3uA/3uF or 1.1V/S

.tran 0 8s 0s .1s startup

[Diagram of the oscillator circuit with components labeled]
Free Waveguide Calculator
Pi and T pad Calculator
Planar Transmission Line Calculator from Rogers

Transmission Line Information

Conventional Microstrip
Using RO4350B™ circuit materials.

The immediate following information is at 2 GHz and the Losses vs. Frequency is given further below, where noted.

Impedance = 50.09 ohms
Effective dk = 2.8131

Dielectric Loss is = 0.0254 dB/in
Conductor loss is = 0.1145 dB/in

Material Name | dk | df | TC dk | Therm Cond
--- | --- | --- | --- | ---
TMM3 | 3.27 | 0.002 | -37 | 0.7
TMM4 | 4.5 | 0.002 | -15.3 | 0.7
TMM6 | 6 | 0.0023 | -11 | 0.72
TMM10 | 9.2 | 0.0022 | -38 | 0.76
TMM10i | 9.8 | 0.002 | -43 | 0.76
Ultralam 3850 | 2.9 | 0.0024 | 100 | 0.2
RO3003 | 3 | 0.0013 | 13 | 0.5
RO3006 | 6.15 | 0.002 | -160 | 0.61
RO3010 | 10.2 | 0.0023 | -280 | 0.66
RO3035 | 3.5 | 0.0017 | -34 | 0.5
RO3203 | 3.02 | 0.0016 | 13 | 0.5
RO3206 | 6.15 | 0.0027 | -212 | 0.63
RO3210 | 10.2 | 0.0027 | -459 | 0.81
HU4003 | 3.55 | 0.0027 | 40 | 0.64
RO4350 | 3.66 | 0.0037 | 50 | 0.62
Planar Transmission Line Calculator from Rogers

Transmission Line Information

Stripline, Edge Coupled
Using RO4350B™ circuit materials.

- Even mode impedance = 36.78 ohms
- Odd mode impedance = 32.73 ohms
- Common mode impedance = 18.38 ohms
- Differential impedance = 65.47 ohms

- Coupling Coefficient = 24.74
- Wavelength in transmission line = 3.084 inches
- Skin depth is = 5.81126107846755E-05 inches

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Free Assorted Tools and Calculators from HP/Agilent
S-parameter plotting tool in AppCAD
Thermal tool in AppCAD

1. Input supply voltage and current.
2. Input RF input and output power.
3. Input thermal resistance for device (and PCB, optional).
4. Input either of the three temperatures.
5. Press Enter (with cursor in temperature input field) to calculate remaining parameters.

- Vin = 8 V
- lin = 1000 mA
- Pin = 20 dBm
- Pout = 33 dBm
- Tj = 150°C
- θJA = 10°C/W
- θja = 2°C/W
- Θa = 77°C
- Pdc = 8000 mW
- ΣPrf = 1095.3 mW
- Pdiss = 6104.7 mW

(Total power dissipated as heat)
PA Biasing Tool in AppCAD
Measured data and models for lumped capacitor and inductors from Murata
System Cascade Analysis Tool
Sonnet 2D EM
Tool Examples
Planar EM Tool from Sonnet Software: Interdigital BPF Example
Frequency = 4.7 GHz
Planar EM Tool from Sonnet Software: Surface Current Density
Frequency = 4.7 GHz

Planar EM Tool from Sonnet Software: Surface Current Density
**FREE WARE:** Software for Electrical Engineering Design

**LT Spice:** Linear and Nonlinear DC and AC
**Serenade SV:** HF RF and Smith Chart w/ Two Port data sets
**QUCS:** Linear and Nonlinear and ADS like interface
**RFSIM99:** Linear RF circuit analysis
**TINA:** TI spice analysis, linear and nonlinear
**APPCAD:** RF Tool box w S-parameters
**PUFF:** S parameters, closed form Transmission lines, microstrip, stripline, pcb discontinuities, multiport s parameters
**ELSIE:** Tonne SW Excellent Lumped element Filter Synthesis tool
**SONNET:** Free 2.5D planar EM Simulator from Sonnet Software Inc
**SYSCAL5LITE:** From Arden Technologies, free system simulator
**ECLIPSE5LITE:** From Arden Technologies, free RF/Microwave Linear Simulator
**CASCADE32:** Free system simulator from Scillasoft Consulting
**Waveguide Calculator:** Free WG calculator from Engineers Club
**QwkPath v3.1:** Microwave Path Calculator from Engineers Club
**http://www.circuitsage.com/tools:** Lots of free online tools
**QUICKSMITH:** Free Smith Chart based linear circuit Simulator ([http://www.nathaniyer.com/qsdw.htm](http://www.nathaniyer.com/qsdw.htm))
**VNAHELP:** Lots of VNA related information
**SPARGRAPH:** Free viewer for s2p files
**AppCAD:** [http://www.hp.woodshot.com](http://www.hp.woodshot.com)
**Analog Devices:** [http://designtools.analog.com/dtDDSSub/dtDDSSubMain.aspx](http://designtools.analog.com/dtDDSSub/dtDDSSubMain.aspx)
**Analog Devices:** [http://designtools.analog.com/dtDiffAmpSub/dtDiffAmpMain.aspx](http://designtools.analog.com/dtDiffAmpSub/dtDiffAmpMain.aspx)
**Analog Devices:** **ADIsimPLL Version 3.3**
**Analog Devices:** **ADIsimRF Version 1.4**
**Analog Devices:** **ADIsimCLK Version 1.3**
Summary/Conclusion:

- CAD Tools necessary for Optimal System Design
- Learning new concepts and be aided by use of free CAD
- Conduct “what if” experiments free of cost and free of smoke
- Good exposure to system concepts and multiple domain knowledge
Thank You

Q & A