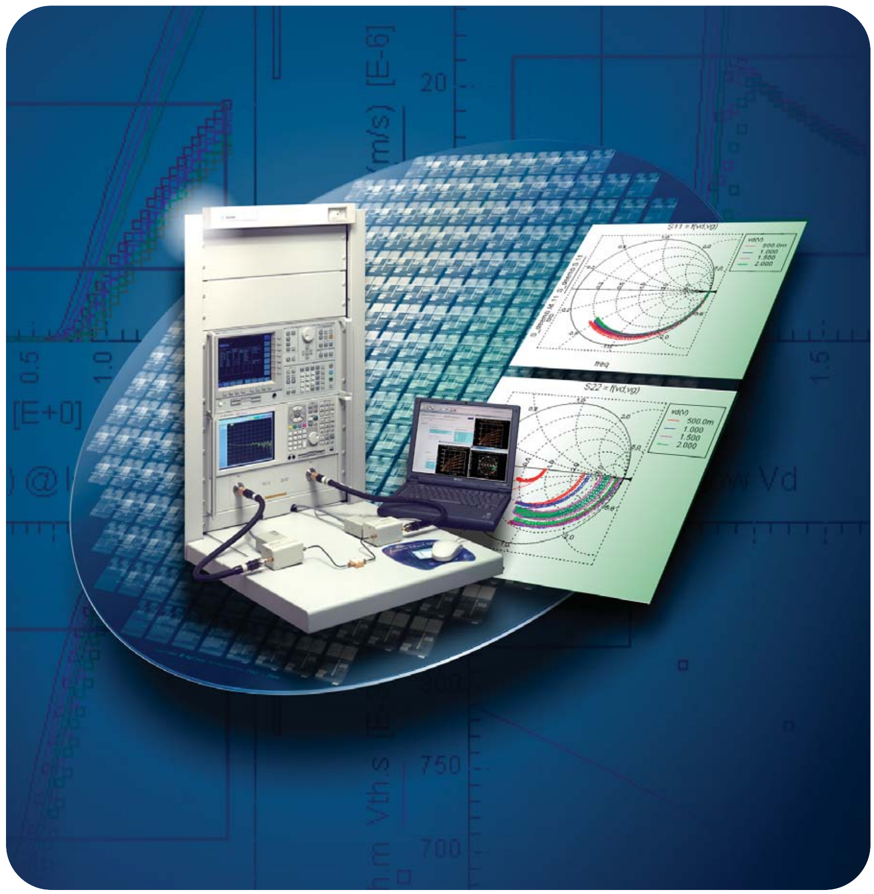
Agilent Technologies IC-CAP Device Modeling Software Release 2006

Technical Overview

Complete and Accurate Parameter Extraction and Statistical Analysis



About IC-CAP

IC-CAP (integrated circuit characterization and analysis program) is device modeling software that provides powerful characterization and analysis capabilities for today's semiconductor modeling. IC-CAP offers device engineers and designers a state-of-the-art modeling tool that fills numerous modeling needs, including instrument control, data acquisition, parameter extraction, graphical analysis, simulation, optimization, and statistical analysis. All of these capabilities are combined in a flexible, automated, and intuitive software environment for efficient and accurate extraction of active devices and circuit model parameters. IC-CAP provides the power to build model libraries for Advanced Design System (ADS) or other commercial simulators.

Features at a glance

- efficient, open and flexible software environment and extraction methodologies
- DC to RF extraction routines for state-of-the-art industry standard models
- unique nonlinear high-frequency Agilent Root models
- easy-to-use windows-style user interface
- powerful data handling capability
- open interface to a variety of instruments and simulators
- complete automated hardware and software integration
- fast links to ADS simulators
- unique boundary models for realistic worst-case modeling
- worldwide training and support

IC-CAP 2006A What's New

New platforms

- MS Windows 2000 and XP platforms supported
- Linux: Red Hat Enterprise 3
- HP-UX 11i and Solaris 8, 9, 10 – (2006B release)

User interface enhancements

IC-CAP 2006 contains breakthrough improvements in modeling visualization.

General highlights

- Plot and trace customization (color, style, etc.)
- Improved graphics and text quality (text, layout, etc.)
- Improved user interface for data and plot manipulation
- Multiple plots per window (Multiplot Studio)

Single plot highlights

- Plot adjustment tools with dedicated menus in each plot area
- Improved text and labeling capabilities
- Multicolor curves for multiple sweeps and higher order sweeps
- Legend for better visualization of higher order sweeps
- Layout optimization to maximize the graphic area
- Graphic analysis (error trace, relative rms/Max. error) of plotted data
- Plot customization to suit personal preferences
- Graphical displays rescale directly from the plot (select a region box)
- Improved rendering of text and numbers with true type fonts

Multiplot highlights

- Unlimited number of plots in the same window
- Easy navigation and settings using right-click menus
- Zooming capabilities allow for examination of a specific plot out of a larger number of displayed plots
- Customize a standard plot appearance for additional plots

BSIM 4.4

- A smarter and more intuitive extraction flow for easier element extraction
- More extraction insight for a more efficient process by utilizing the new graphics features
- Guided interaction to adopt the extraction strategy to a certain process
- Guidelines and tools to use the open code strategy of IC-CAP in an efficient way for modifications
- Portability of customization to future versions
- Tuning and optimization capabilities to tailor extraction to your process
- Quick, accurate extraction process for streamlined characterization

Other enhancements and updates

The IC-CAP statistical package is now standardized on the ADS Linear and Transient simulators. The SPICE simulator is also included in IC-CAP 2006A.

IC-CAP and Today's Modeling Challenges

The fast-paced semiconductor industry faces continuing challenges to maximize product performance and yield, decrease time-to-market, and reduce production costs. As device geometries get smaller, the need to use accurate models and to control statistical variations in device processing performance becomes more important.

Today's engineers face increasing demands for higher speed and greater bandwidth. Typical circuit operating frequencies continue to advance well into the RF and microwave frequency range. Accurate device models are critical to circuit simulation convergence and accuracy. Device models that are accurate at DC level are no longer sufficient in many applications. Circuit designers need models that can accurately predict device behaviors at DC level as well as RF and microwave region.

The different process technologies require a variety of models that can quickly adapt to the unique processes. A modeling software must be able provide modeling engineers the flexibility to modify and extend model parameters beyond those offered by standard models. To optimize performance and control variations, device designers and process engineers need both accurate models and statistical analysis capabilities. For circuit designers, both tools are a requirement for determining nominal performance as well as extreme (worst-case) behaviors.

Meeting the challenges

This latest release of IC-CAP addresses these challenges and provides significant competitive advantages to companies within the semiconductor industry.

Accurate Agilent proprietary and industry standard models

IC-CAP contains both accurate models and advanced statistical analysis for building and maintaining up-to-date model libraries. Within a single environment, you can use IC-CAP to automate measurements, simulate device performance, extract data, optimize model parameters, perform advanced statistical analysis, and generate worst-case models. IC-CAP provides extraction routines for industry standard as well as Agilent proprietary models for Diodes, BJT, MOSFET, MESFET, HEMT, noise, thermal model, and others. Extraction modules offer complete DC to RF parameter extraction capabilities. In addition, IC-CAP supports models and extraction routines that are developed by third parties, as well as numerous other simulation software packages, to accommodate a wide range of customer requirements.

For optimization of process control variation, IC-CAP offers a statistics package, which includes several statistical methods and a proprietary non-parametric boundary modeling for a realistic worst-case analysis.

RF and microwave modeling capabilities

Agilent EEsof EDA RF modeling expertise is built into our IC-CAP modeling configurations, making them the tools of choice for engineers who are involved in high-frequency device modeling.

Accurate modeling of RF effects requires reliable measurement data. Building on proven strengths in RF/microwave test and measurement, Agilent EEsof EDA provides configurations for a variety of modeling systems for DC, LCRZ, RF, and isothermal modeling.

IC-CAP extraction modules for proprietary and industry standard models include RF dependent parameter extraction, ensuring your models suitable for high frequency circuit simulations.

The most flexible software environment

IC-CAP operates in an open and flexible software architecture. All setups and macros are open for user modifications. Using parameter extraction language you can build your own models or extraction methodologies directly into IC-CAP. The IC-CAP open interface allows you to write your own measurement drivers to control instruments using user C language. Together with our modeling systems, IC-CAP offers a complete, integrated modeling solution for today's semiconductor industry.

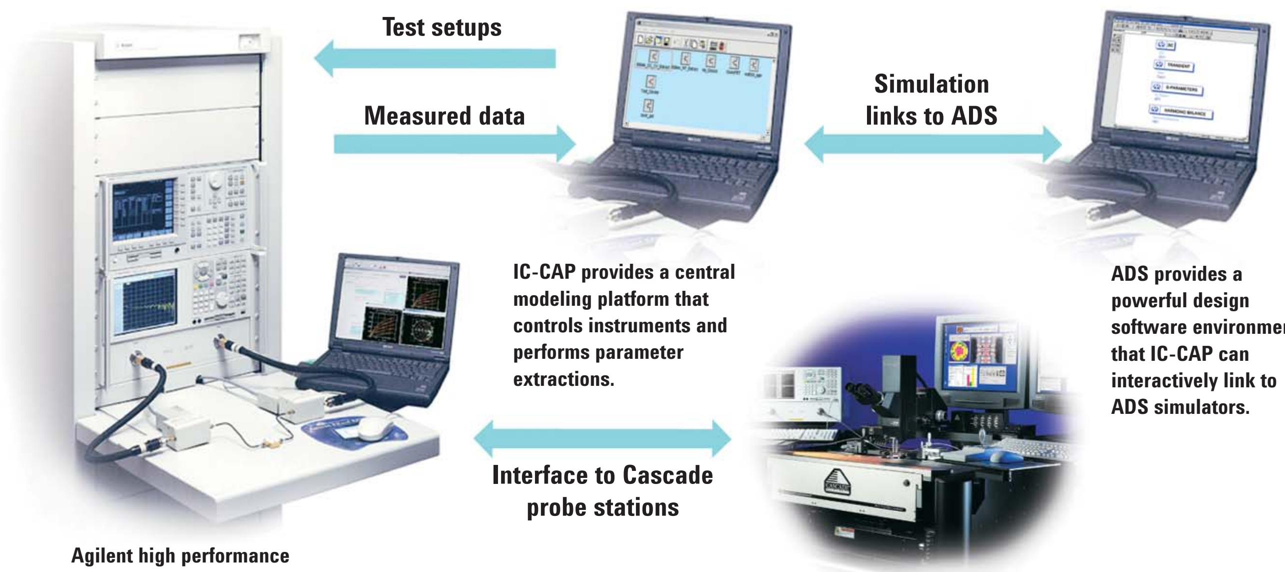
A Complete Device Modeling Solution

Successful device modeling requires thorough understanding of the complex integration between the measurement hardware and the modeling software.

Agilent EEsof EDA provides a complete set of tools for a fully integrated solution for device modeling engineers. This toolset eases the early challenges in establishing a new device modeling and simulation laboratory.

IC-CAP software is a powerful modeling tool that automates the Agilent's recommended modeling configurations. The systems provide a variety of modeling capabilities including DC, LCRZ, CV, RF and 1/f noise measurements. To fully automate your measurement environment, these systems can be readily interfaced to Cascade Microtech's probers for a complete on-wafer solution.

The measured data are collected and stored in IC-CAP for parameter extractions and optimizations of various industry standard models. IC-CAP provides links to the ADS simulators that include the DC, transient, S-parameter, and harmonic balance simulators. The extracted and optimized models can be directly imported into ADS for accurate model libraries.



IC-CAP provides a central modeling platform that controls instruments and performs parameter extractions.

ADS provides a powerful design software environment that IC-CAP can interactively link to ADS simulators.

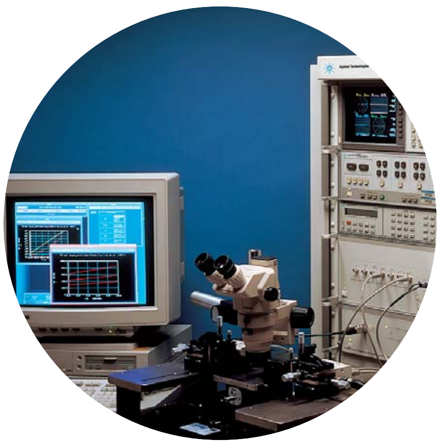
Agilent high performance modeling configurations for complete DC-to-RF device characterizations.

Cascade Microtech's probe system and solution provides state-of-the-art probers with WinCal software for advanced, automated system calibration.

Device Modeling Configurations

Make accurate measurements with Agilent device modeling systems

Accurate device characterization starts with accurate and reliable measurement systems. Agilent application-focused modeling configurations offer single-source, solutions for linear device measurements. Although standard modeling hardware configurations are available, most configurations can be customized and tailored to your specific requirements.



Performance modeling hardware configurations

Agilent EEsof EDA can provide configuration recommendations to help you create a modeling hardware system that fits your measurement needs. These configurations are high-performance modeling systems that contain complete DC-to-RF device measurements and modeling capabilities for today's semiconductor device processes.

The configurations include an RF subsystem, using a high-performance network analyzer (PNA series) with exceptionally high dynamic range, very low trace noise, and fast measurement time with improved usability. Each configuration includes a PNA that offers a specific measurement frequency range. For example, the E8362B (10 MHz to 20 GHz) is part of the 20-GHz hardware configuration.

Each configuration suggests a pair of bias networks for combining the DC and RF signals and making standard Kelvin measurements.

The DC subsystem is configured around the 4156C or the E5270B precision semiconductor parametric analyzer for high-precision DC measurements.

For additional modeling hardware resources visit our IC-CAP website: **www.agilent.com/find/eesof-iccap**

Table 1 shows a representative of the configurations based on the PNA family of network analyzers.

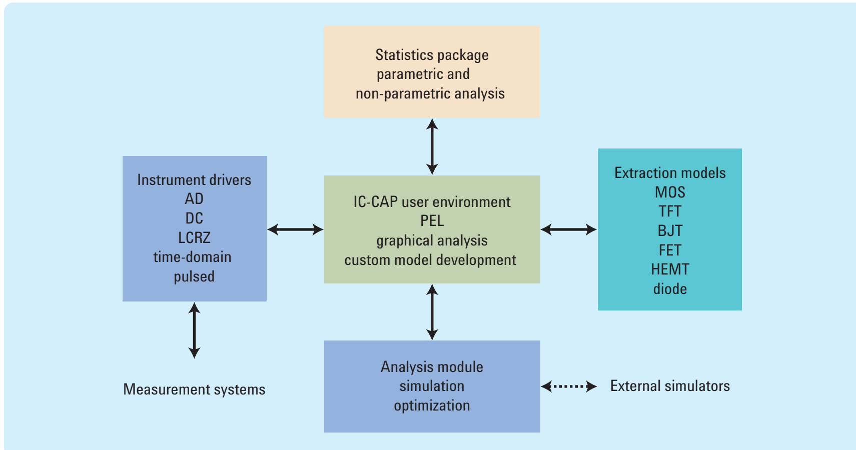
Table 1. PNA configurations and frequency ranges

Frequency Range[1]	PNA	4156C	E5270B
45 MHz to 20 GHz	E8362B	✔	✔
45 MHz to 40 GHz	E8363B	✔	✔
45 MHz to 50 GHz	E8364B	✔	✔
45 MHz to 67 GHz	E8361B	✔	✔
10 MHz to 110 GHz	N5250A	✔	✔

1 Lower frequency is limited by the bias networks at 45 MHz except for 110 GHz configuration.

IC-CAP Modeling Software

IC-CAP modeling software offers modular products. You can choose precisely the modules that are required. Central to IC-CAP platform is the IC-CAP software environment, which supports graphical analysis, parameter extraction language, and custom model and user interface development. An analysis module is required in most modeling applications for simulation, optimization and interfacing to external simulators. IC-CAP supports an extensive list of measurement instruments including DC, LCRZ, AC, pulsed, and noise measurements.



IC-CAP is a modular software product that allows you to choose precisely the tools you need for your modeling application.

Device modeling with IC-CAP

A typical modeling procedure:

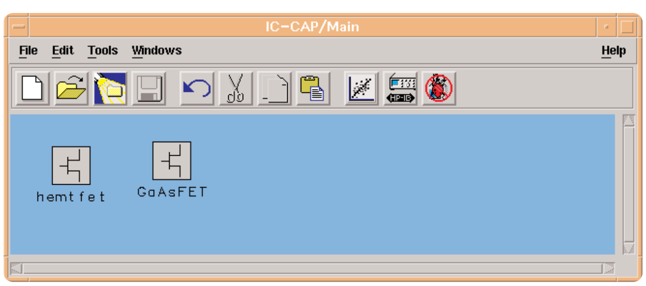
- Select a model based on your application (MOSFET, BJT, and so on).
- Make DC, CV, and RF measurements.
- Extract model parameters from measured data using IC-CAP extraction modules.
- Simulate extracted model parameters using model equations from IC-CAP built-in, user developed, or external simulator models.
- Tune and optimize model parameters to best fit measured and simulated results.
- Use statistics package to build a statistical model.

IC-CAP user interface

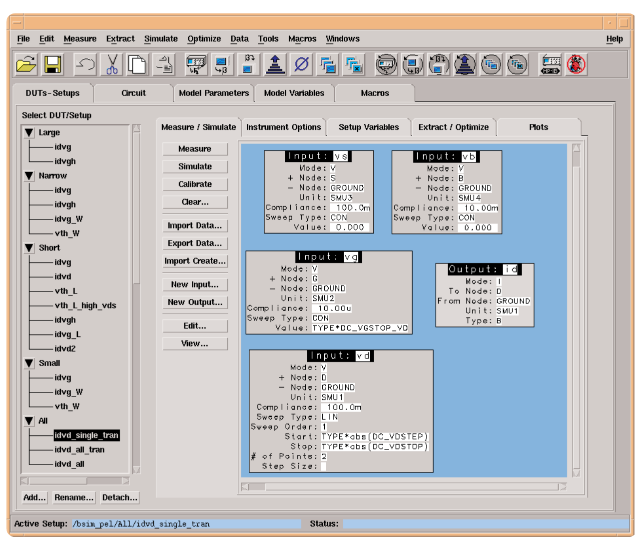
The IC-CAP user interface makes it easy to open or create models, set up hardware drivers for measurements, extract parameters, simulate, and optimize model parameters. Interface items such as icons, push buttons, and menu bars make IC-CAP into a user-friendly product similar to the latest windows-style software products.

The basic user interface works like this:

- From the IC-CAP main window, you click on icons to open existing model files or create new ones.
- You can browse between different folders for measurements, simulations, extraction/optimization and many others within a model file.
- Within each folder, you can click on the ADD buttons to create new setups such as inputs, outputs, and plot definition.
- You can easily edit circuit deck, modify parameters, write macros, define variables, and more. Most IC-CAP functions are performed by simply clicking buttons such as: Measure, Simulate, Display Plots, Execute, and so on.



From the IC-CAP main window, you can create a new model file, open an existing model file, open existing example model files, configure your hardware, or open a statistics project.



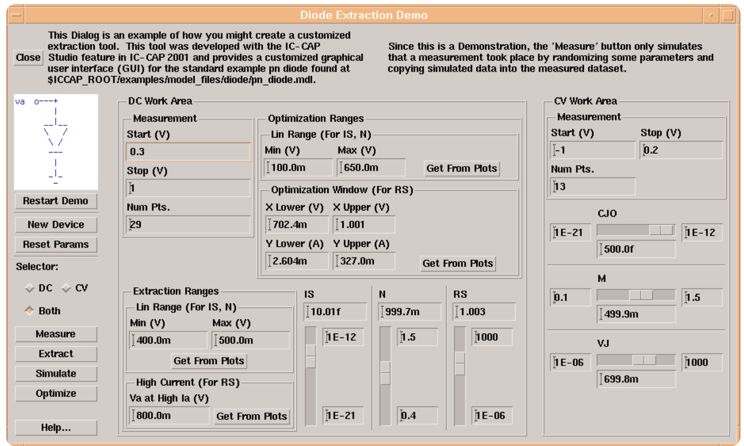
Measurement, extraction, simulation, and optimization are all controlled from the model window.

IC-CAP Studio

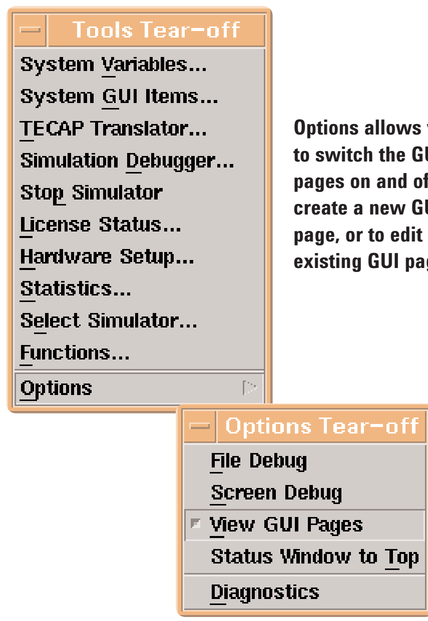
IC-CAP Studio adds powerful capabilities for custom graphical user interface development to the highly flexible IC-CAP software environment. IC-CAP Studio provide users with the ability to directly generate a well documented, simplified, and intuitive in-house extraction routines that tremendously cut down the time to go through a complete modeling process. An engineer uses IC-CAP Studio to develop a user interface that automates and simplifies an entire measurement or extraction process flow. The model file can then be shared and exchanged with other colleagues or outside customers who can easily comprehend the flow and quickly perform the necessary measurement and extraction steps.

Developing a user interface using IC-CAP Studio is a straightforward task. No language programming is required. A user simply turns on the IC-CAP Studio from the main window, and the entire development becomes a click-of-a-button experience. There are drop-down menus that allow a developer to pick and choose UI items from the list. The different interface levels can be organized into hierarchical layers, which can interact with one another. In addition, executable transforms and automation macros can be invoked from the interface level, thus making it possible to perform and automate a complete measurement-to-extraction process from the user interface.

Once the extraction UI is created, it can be saved in the model file, which can be shared by another IC-CAP user.

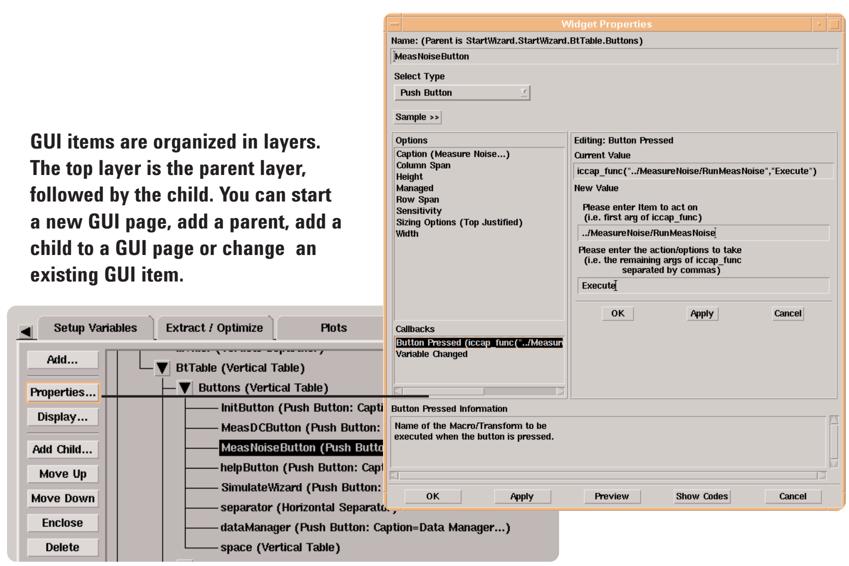


Example: Diode model extraction routines developed using IC-CAP Studio.



Options allows you to switch the GUI pages on and off, to create a new GUI page, or to edit an existing GUI page.

GUI items are organized in layers. The top layer is the parent layer, followed by the child. You can start a new GUI page, add a parent, add a child to a GUI page or change an existing GUI item.



Data acquisition

IC-CAP makes automated testing easy with its built-in instrumentation drivers. All of the necessary measurements are defined and implemented from the software, allowing remote testing.

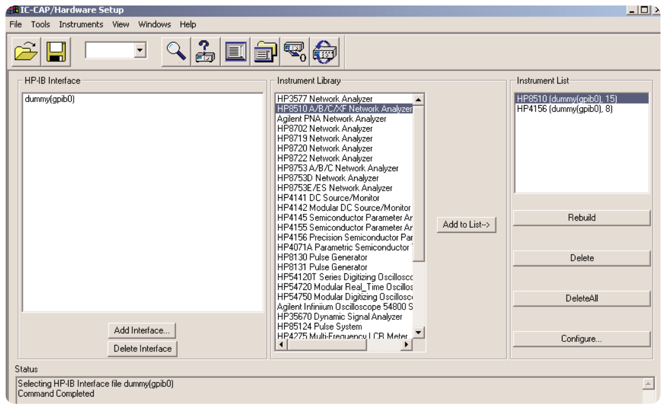
Drivers for a wide variety of DC parametric analyzers, network analyzers, LCR meters, pulse generators, and oscilloscopes are included in IC-CAP and are easily specified in the new hardware manager. Drivers for several third-party probe stations and switch matrixes are also included. The open measurement interface allows you to add custom drivers for other instruments from Agilent Technologies and other vendors.

Measurement configuration

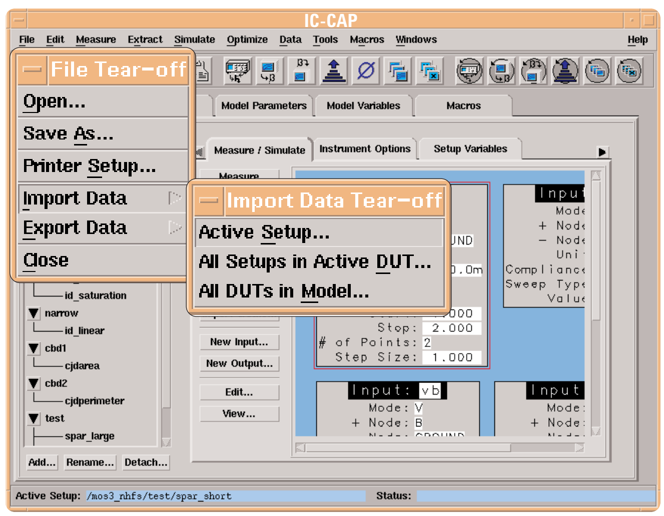
Stimulus/response measurements of the device under test (DUT) are configured by setting DC voltages and currents, RF frequencies, and other user-defined parameters in IC-CAP. Multiple measurement setups can be created and defined, including fixed or swept stimulus values in several different modes, such as linear, log, exponential, or list. Compliance limits can also be set to prevent device damage.

The IC-CAP data manager

All the data for a collection of device geometries, temperatures, and so on, can be stored in a single file in ASCII format. Subsets of this file can be imported into a given setup as required by specific extractions. In this way, importing data into IC-CAP is like a virtual measurement. This capability also allows for separate measurements and extractions so you can have multiple models for only one set of measured data. The data file can be created from IC-CAP macros by executing new transforms. Additionally, you can also create your own data files.



The hardware manager makes it easy to add instruments with a click of a button. You can remotely drive measurements on a LAN. For example, the HP 2050A LAN/HP-IB Gateway (LAN box) can be connected to your HP-IB instruments and then accessed over your LAN by its address. This means several workstations can remotely drive the same measurement system.

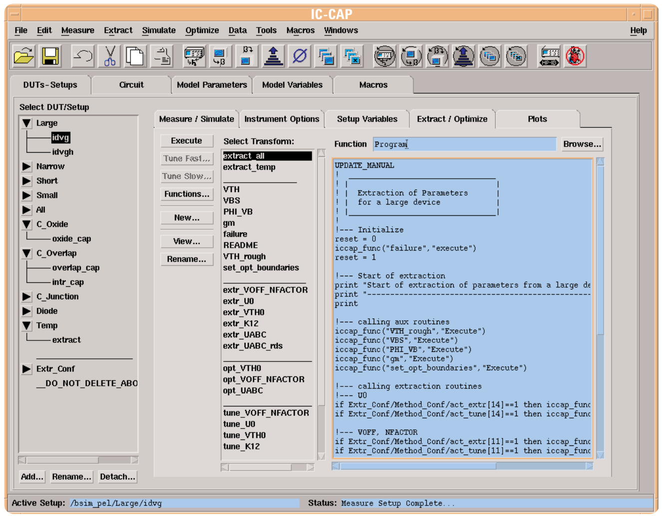


The IC-CAP data manager provides a convenient and simple way to separate the measured data from extraction. You can easily import and export data from the model window or from a setup window.

Parameter extraction and PEL

One of the powers of IC-CAP lies in its open architecture and its parameter extraction language (PEL). PEL is an IC-CAP language that is quite similar to the HP BASIC. PEL allows users to write transforms and macros. Transforms are programs that work with data, and macros are for automation. Model parameters are extracted by applying mathematical transforms to measured data. Simple extractions can be created by writing an equation directly in the IC-CAP transform window. More intricate transforms can be created by using PEL.

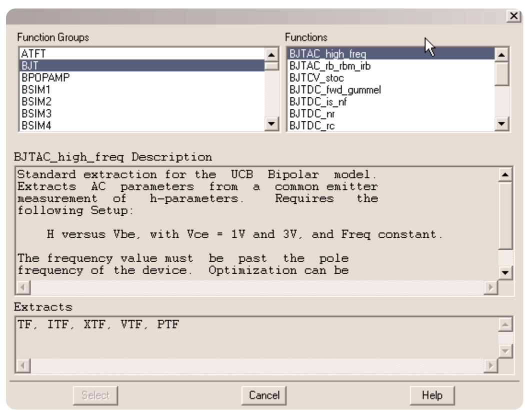
PEL allows you to interactively develop new models and extraction routines and modify existing extraction modules, making IC-CAP an extremely open and flexible working environment.



IC-CAP's built-in parameter extraction language lets you create your own model or modify the existing model easily. For example, the BSIM3 parameter extraction routines were developed using PEL and is open to modification.

Function library

The function library provides convenient access to routines for trigonometric, complex, statistical, two-port, and matrix computations. For example, the two-port function can be used to convert between two-port data types, such as S-parameters, to Y-parameters. The function library can also be augmented with user-defined functions. These can be written in the C language and linked into IC-CAP.



IC-CAP function library provides easy access to many built-in functions.

Circuit simulation

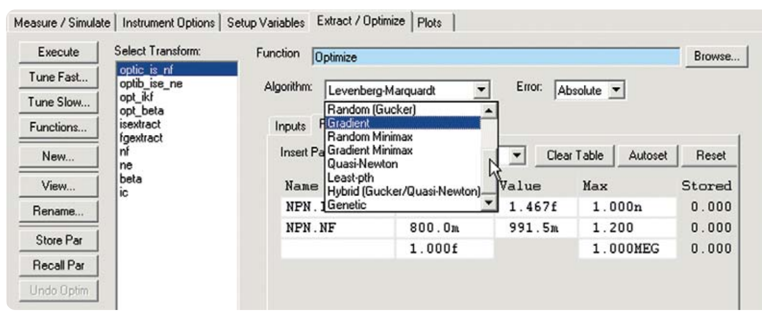
After a preliminary list of model parameters is extracted, a simulation can be performed. Simulation results can be plotted together with measured data to see how well predicted device performance compares to measured data. The simulation is based on a continuously updated parameter table and the user-specified circuit deck, which may include parasitics in the measurement setup. IC-CAP includes three SPICE simulators and provides direct links to several external simulators, as listed in Table 1. Links to simulators that are not directly supported can be created using the open simulator interface in IC-CAP.

Parameter optimization

IC-CAP contains 13 robust optimization algorithms. Using a combination of different optimization algorithms can be a real advantage to enhance the model's fit and resolve an optimizer's convergence problem. A large number of parameters can be optimized to a large number of weighted data sets. You can specify your desired optimization settings such as the minimum and maximum parameter values, upper and lower data boundaries, and maximum error limits. The sensitivity analysis mode shows you which parameters have the greatest effect on a particular optimization. This exposes the dominant parameters that should be accurately extracted before optimizing other interrelated parameters.

IC-CAP Optimization Algorithms

Algorithm	Description
Levenberg-Marquardt	Non-linear search method with least-squares error function.
Random	Random search method with stochastic gradient error function.
Hybrid (Random/LM)	Combination of Random and Levenberg-Marquardt algorithms and error functions.
Sensitivity Analysis	Single-point or infinitesimal sensitivity analysis of a design variable. Prints partial derivatives with respect to each parameter.
Random (Gucker)	Random search method with least-squares error function.
Gradient	Gradient search method with least-squares error function.
Random Minimax	Random search method with minimax error function.
Gradient Minimax	Gradient search method with minimax error function.
Quasi-Newton	Quasi-Newton search method with least-squares error function.
Least Pth	Quasi-Newton search method with least Pth error function.
Minimax	Two-stage, Gauss-Newton/Quasi-Newton method with minimax error function.
Hybrid (Random/Quasi-Newton)	Combines the Random and Quasi-Newton search methods.
Genetic	Direct search method using evolving parameter sets.



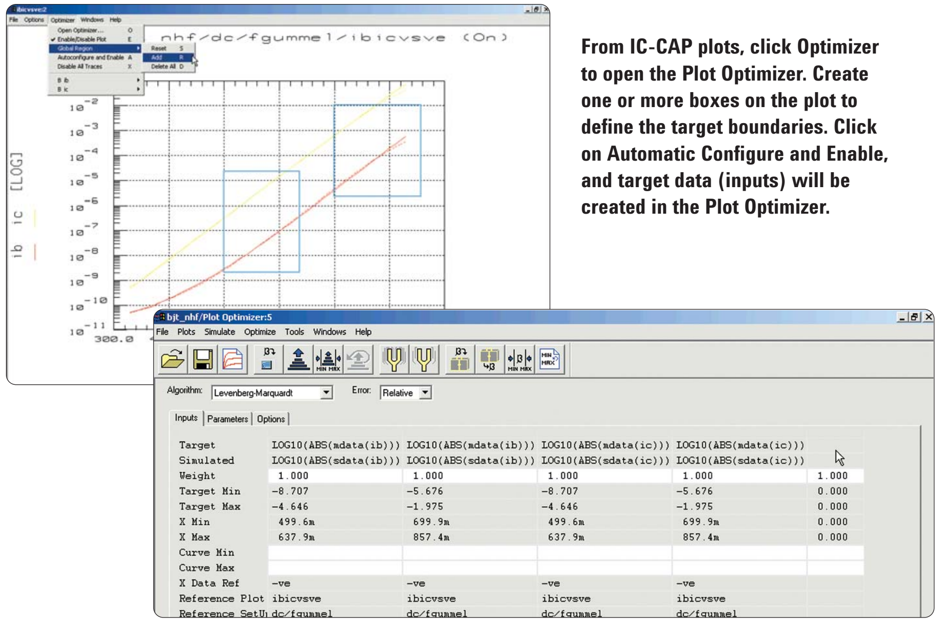
IC-CAP offers 13 algorithms to help with model fitting and convergence.

IC-CAP Modeling Software – *Continued*

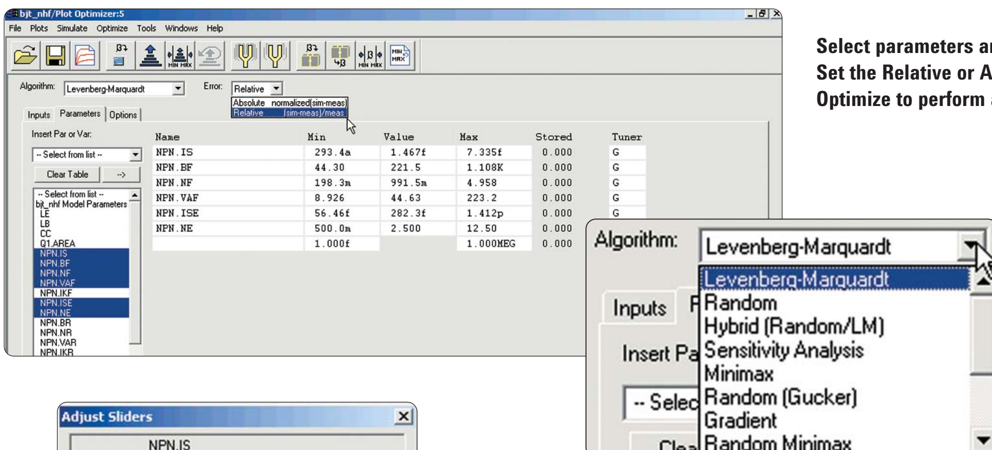
Optimization made easy with the plot optimizer

The Plot Optimizer is a user interface that enables you to quickly set up all parameter optimization tasks on the fly. You can open the Plot Optimizer from every IC-CAP plots and automatically load the measured data into the Plot Optimizer. With a few mouse clicks, you can quickly select boxes on the plots to set multiple minimum and maximum data boundaries.

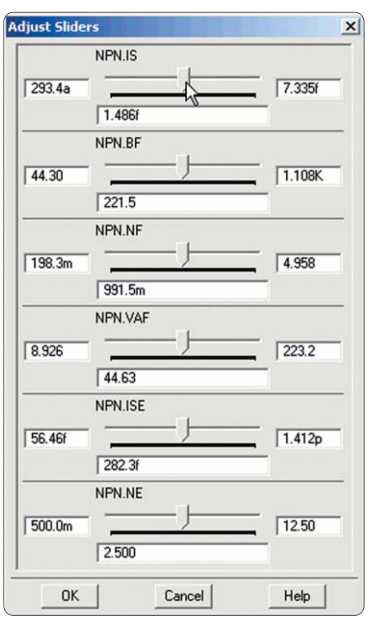
Finally, you can save the optimization set up as an Plot Optimizer file to reuse it later, or you can save it as a transform that can be executed in a push- button, automated extraction/optimization process.



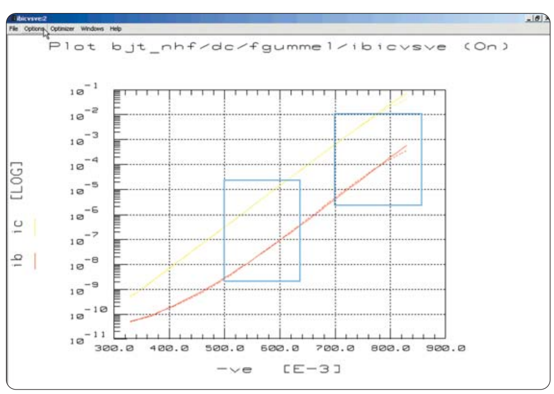
From IC-CAP plots, click Optimizer to open the Plot Optimizer. Create one or more boxes on the plot to define the target boundaries. Click on Automatic Configure and Enable, and target data (inputs) will be created in the Plot Optimizer.



Select parameters and set the Min and Max values. Set the Relative or Absolute Error. Then click Optimize to perform automatic optimization.



Click on the Tuner button to fine tune the model parameters for better fit before or after an optimization.



Save the optimization as a Plot Optimizer file for re-use or as a transform to be used in an automated extraction/optimization process.

Efficiently visualize more data with new plot area tools and MultiPlot Studio – multiple plots in a single window

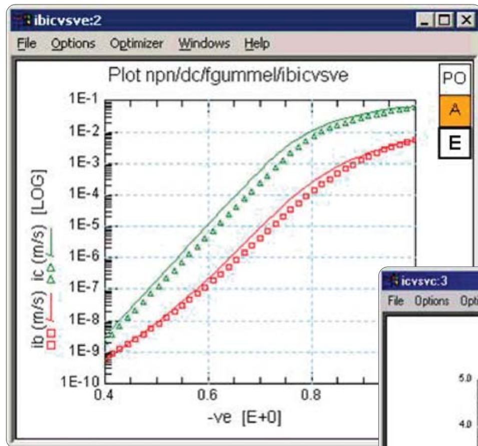
New for IC-CAP 2006 is the introduction of advanced plot area tools and MultiPlot Studio. These new plotting capabilities allow better visualization of large amounts of data and provide a more integrated model extraction process.

Highlights of the new single plot capabilities include:

- Plot adjustment tools in each plot area with dedicated menus
- Improved text and labeling capabilities
  - Use of multicolor curves for multiple sweeps and higher order sweepsLegend for better visualization of higher order sweeps
  - Layout optimization to maximize the graphic area.
  - Graphic analysis (error trace, relative rms/Max. error) of plotted data
  - Plot customization to suit personal preferences
  - Graphical displays rescale directly from the plot (select a region box)
  - Improved rendering of text and numbers with true type fonts

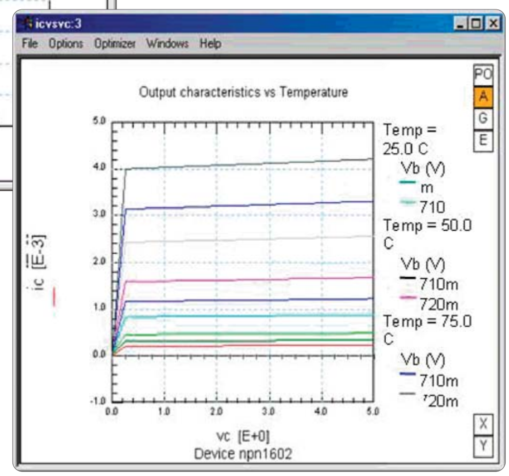
Highlights of MultiPlot Studio include:

- Unlimited number of plots in the same window
- Easy navigation and settings using right click menus
- Zooming capabilities allow for examination of a specific plot out of a larger number of displayed plots
- Customize a standard plot appearance for additional plots

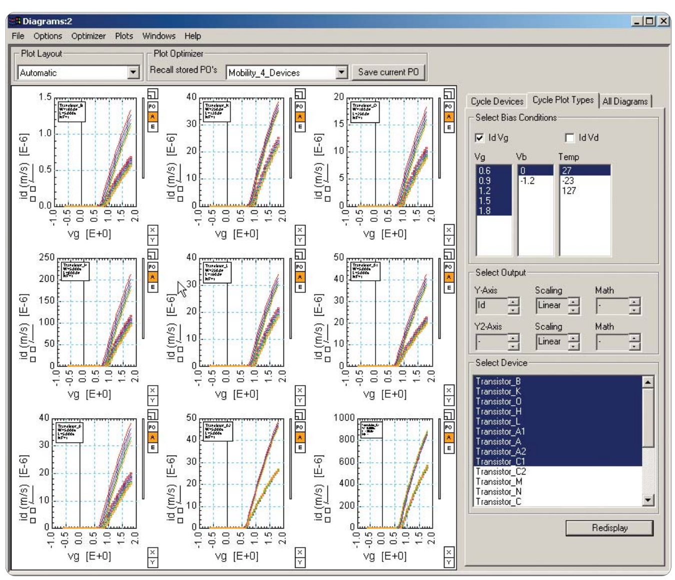


New area tools allow for easy access to the Plot Optimizer, Autoscaling, and Error function with just a click of the mouse.

Example of a single plot IC-CAP window. Easily view and manipulate your plots to fit your extraction needs.



Customize plot and axis titles. Color and data legend capabilities keep multiple sweeps and measurement variables straight.



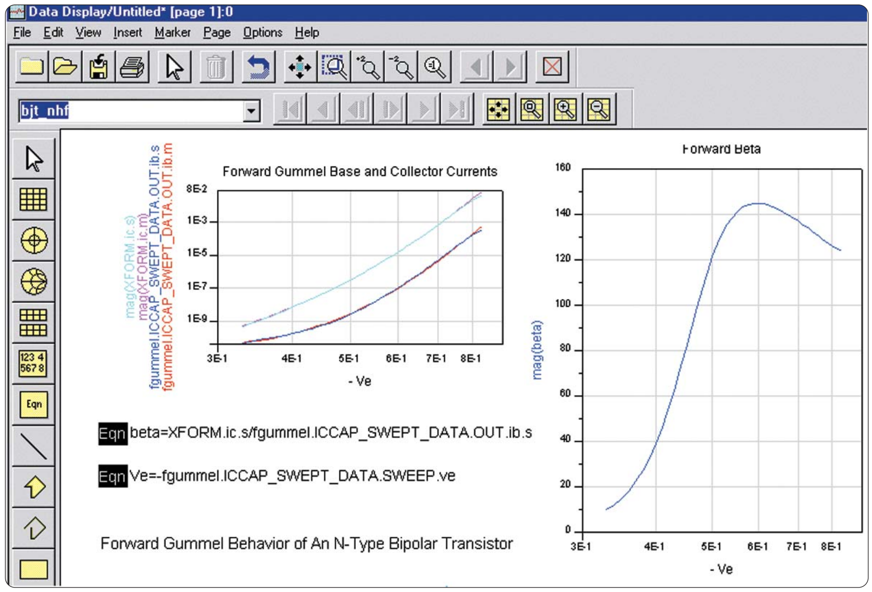
Example of a MultiPlot Studio window with an integrated user defined GUI.

IC-CAP Data Display

The Data Display is a powerful environment for viewing and analyzing data sets. After you finish extracting and simulating the model, you can automatically save the data in data sets. The Data Display also contains many powerful and flexible plotting capabilities for you to generate integrated reports and documentation. You can also incorporate other types of data sets such as ADS simulation, network analyzers, and CITIfiles.

The Data Display includes the following features:

- Display data in a variety of plots and formats– rectangular plots, polar plots, Smith charts, and stacked plots. Linear traces, histograms, scatter plots, and spectral plots also are available. Data can also be displayed in digital and wide-word (bus) data formats. Numerical data can be viewed in lists.
- Create plots with more than two axes.
- Add markers to traces to read specific data points
- Write mathematical equations to perform complex operations on data, and display the results
- Add text and drawing objects to enhance your documentation
- Edit plot titles and axis labels, equations, text, drawing objects, and column headings in lists.

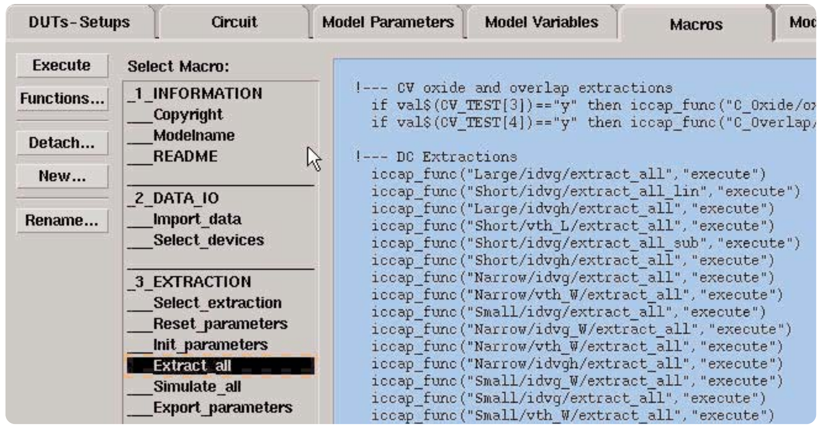


An IC-CAP data display.

IC-CAP Modeling Software – *Continued*

Automation with macros

Tasks within an extraction, or even entire extraction routines, can be automated with macros. A macro is a single command that executes a series of IC-CAP commands, functions, and PEL programs. With macros, extraction techniques developed in R&D can be automated and leveraged to your production areas where minimal user interaction and high productivity are desired.



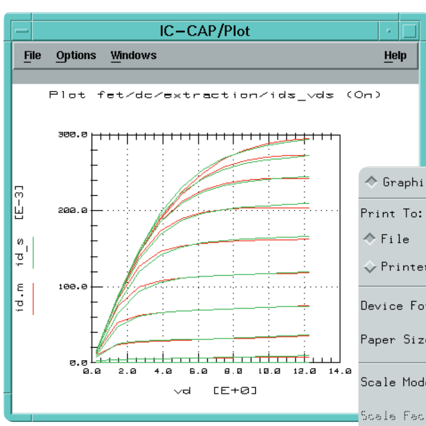
IC-CAP's macro language allows you to customize and automate an entire extraction process as well as develop your own instrument interface.

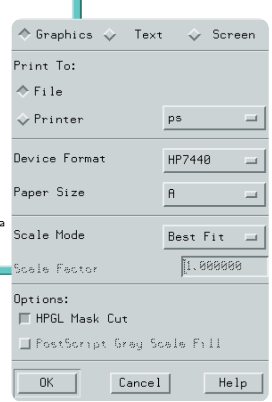
Graphical analysis

Your measured data can be analyzed using the IC-CAP color display in linear, log, real/imaginary, polar, Smith chart, and tabular formats. Statistical distribution of the data can also be displayed. You can show simulated and transformed data such as derivatives on the same plot. Several analysis tools let you determine data points and slopes, making it possible to extract parameters directly from the plotted data. Once the data is analyzed, the IC-CAP interactive format allows you to quickly qualify and/or modify measurement setups and take additional measurements if necessary. The plots are updated automatically with each measurement.

Circuit modeling

IC-CAP is not limited to modeling of discrete devices. Modeling circuits, such as logic gates and op amps, is a natural extension of modeling single devices. IC-CAP's flexible structure easily allows measurement of circuit characteristics, extraction and optimization of model parameters, and simulation of the circuit's performance. One of the advantages of simulating circuits with IC-CAP is the increased level of analysis available. IC-CAP allows you to sweep more parameters than with most stand-alone SPICE simulators. For example, you can simulate a circuit's behavior over varying bias conditions, component values, and temperature, all in the same simulation.



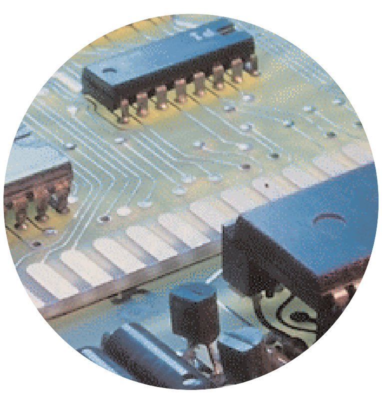


Measured, simulated, and transformed data can be simultaneously displayed with IC-CAP's flexible plotting capabilities.

IC-CAP Extraction Modules

IC-CAP provides turn-key extraction modules for a wide range of popular device models. In addition, IC-CAP allows you to develop custom model equations and extraction techniques. The built-in extraction modules are easy to use and include the appropriate measurement setups, plot definitions, mathematical transforms, optimization routines, and automation macros to help you get started modeling quickly. You can also use these extraction modules as a foundation or template for building custom models using your own extraction techniques.

IC-CAP covers a wide range of model types such as diodes, MOS, BJT, MESFET/HEMT, noise, and many others. There are several models for each type of device from which to choose. IC-CAP supports the latest industry-standard models with highly effective and automated extraction algorithms, including several high-frequency models with unique techniques, for those special applications where the standard models will not fit. Unique models from Agilent EEsof EDA (such as the root and EE models) are also used in the Advanced Design System high-frequency nonlinear circuit simulators.



Noise Modeling

1/f noise modeling package

The 1/f noise or flicker noise is an important noise source generated at low frequencies. Accurate measurement and modeling of 1/f noise for deep sub-micron CMOS, BJT, FET and HBT devices as well as RF passive components are critical to many RFIC designs. For example, the 1/f noise shows up as phase noise in an oscillator design where it mixes to the oscillation frequency, causing the oscillator to become unstable. A noisy local oscillator signal can degrade a receiver's useful dynamic range and selectivity, making it difficult to recover a signal buried in the noise.

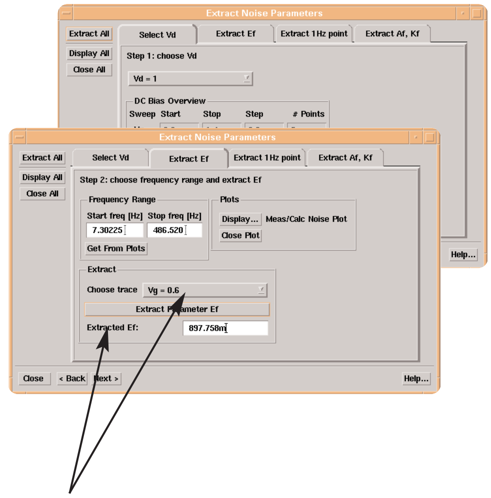
The package offers the following benefits:

- repeatable measurement solution
- accurate and reliable measurement system
- extraction routines that are fully automated, fast, efficient, and easy-to-use

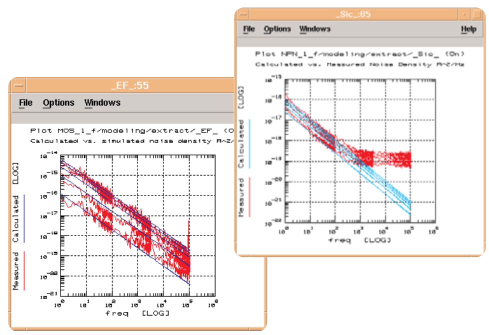
The extraction routines are developed within IC-CAP. The model files with their DUT setups and macros are open to user modifications. Starting the model files will interactively invoke wizards and user interface dialogues that will guide you step-by-step through the entire process of measurement, extraction, and simulation. The full measurement to extraction and simulation process becomes push-button.

A critical element in noise modeling is a reliable and repeatable measurement system. IC-CAP provides the drivers to control and automate instruments such as the Agilent 4142B/4156C modular DC source/precision semiconductor parameter analyzer for DC measurements and the Agilent 35670A dynamic signal analyzer for noise measurements.

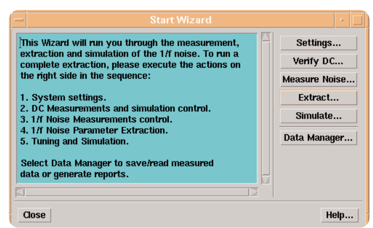
The package offers 1/f noise modeling for both MOSFET and BJT devices.



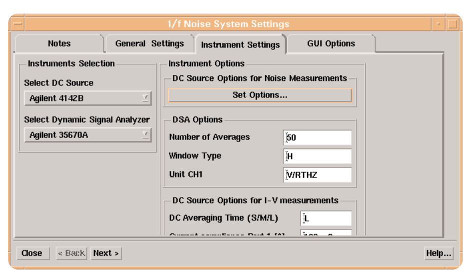
Extract parameter EF at a given Vg.



Extraction of MOSFET 1/f noise.



This intuitive start wizard walks you through all the steps of a successful parameter extraction.



Setting up instruments and other measurement conditions is simple with the wizard-based user interface.

MOS Models

IC-CAP MOSFET models:

IC-CAP MOSFET models:
- UCB BSIM4v4 model
- UCB BSIM3v3.2.4 model
- Philips MOS Model 9
- UCB MOS Level 2,3 model
- Agilent Root MOSFET model

About the BSIM4v4 MOSFET model

First released in 2000 from UC Berkeley, the BSIM4 model is an industry standard model for MOSFET devices. The model addresses important short channel effects typically encountered by sub-0.13 micron devices. The major improvements and additions over the BSIM3 model include:

- A new model of the intrinsic input resistance for both RF, high-frequency analog and high-speed digital applications.
- A flexible substrate resistance network, which is important for RF modeling.
- New induced gate noise model.
- Non-Quasi-Static (NQS) Model.
- Gate direct tunneling current model.
- Layout dependent parasitic model for multi-finger devices.
- Quantum mechanical charge-layer-thickness model.
- Gate-induced drain leakage (GIDL) current model.
- Improved unified 1/f noise model.

About the BSIM3v3.2.4 model

The BSIM3v3 model is a physics-based, scalable MOSFET SPICE model. Accepted as the industry's first standard model in 1996, the BSIM3v3 model is used widely today in circuit simulation and model development by most semiconductor and IC design companies. The BSIM3v3 model covers the following major effects:

- Short and narrow channel effects on threshold voltage
- Drain Induced Barrier Lowering (DIBL)
- Mobility degradation
- Carrier Velocity Saturation
- Channel Length Modulation
- Substrate current induced body effect (hot electrons)
- Non-uniform vertical and lateral doping effects
- Bulk charge effect
- Sub-threshold conduction

The IC-CAP BSIM3 and BSIM4 Modeling Packages feature:

- DC, CV and temperature dependent model parameters extraction with geometry scaling and binning.
- Easy to use toolkits with the latest graphical user interface.
- Open and flexible extraction methodologies.
- Automatic generation of HTML documentation.
- Automatic failure checking mechanism during measurement and extraction process.
- Efficiently handling large data sets.

The BSIM3 and BSIM4 Modeling Packages offer:

- A new user interface that makes BSIM3 and BSIM4 modeling easy and convenient.
- A complete and accurate scalable DC model that fits a wide range of device geometry.
- An accurate binned model for ultra-short channel devices with efficient boundary continuity checking mechanism.
- Reliable RF measurement routines with effective de-embedding methods and highly accurate RF parameter extraction methodologies.
- Highly accurate RF extraction methodologies with enhanced, scalable RF gate and substrate resistance models.
- An open and flexible extraction package that allows you to add extensions and make modifications to enhance DC and RF model accuracy.

Developed through a partnership with Advanced Modeling Solutions (www.admos.de), the BSIM3 Modeling Package provides complete DC to RF modeling for the BSIM3v3.2.4 model.

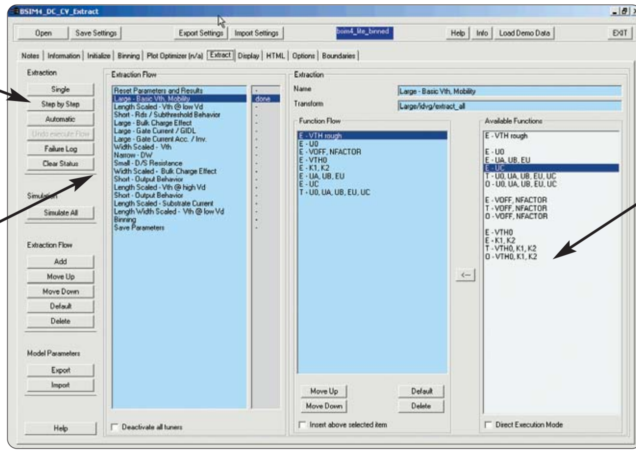
The BSIM4 Modeling Package supports the BSIM4v4 model. The modeling approach is based on direct extraction from the physical model, resulting in more realistic parameter values and thus avoiding convergence problems during circuit simulation. The "smart" extraction approach usually yields an excellent fit between measured and simulated data, requiring little tuning and optimization.

Where fine-tuning and optimization is necessary, the extraction process guides you through predefined optimizer and tuner steps. The user interface incorporates a convenient parameter setup constructed around the MultiPlot Studio. The extracted DC and RF parameters take advantage of IC-CAP's powerful optimization algorithms to best fit the measured data. Changes in tuning parameters are seen in real time in the displayed plots within MultiPlot Studio.

The user interface makes BSIM4 modeling easy

Make a single DC extraction routine or a fully automatic extraction at the push of a button.

An example of the BSIM4 pre-defined extraction routines ready to extract the standard BSIM4 model. You can also configure the flow of extraction routines. The routines written in the open-source Parameter Extraction Language (PEL) can also be modified in the model file.

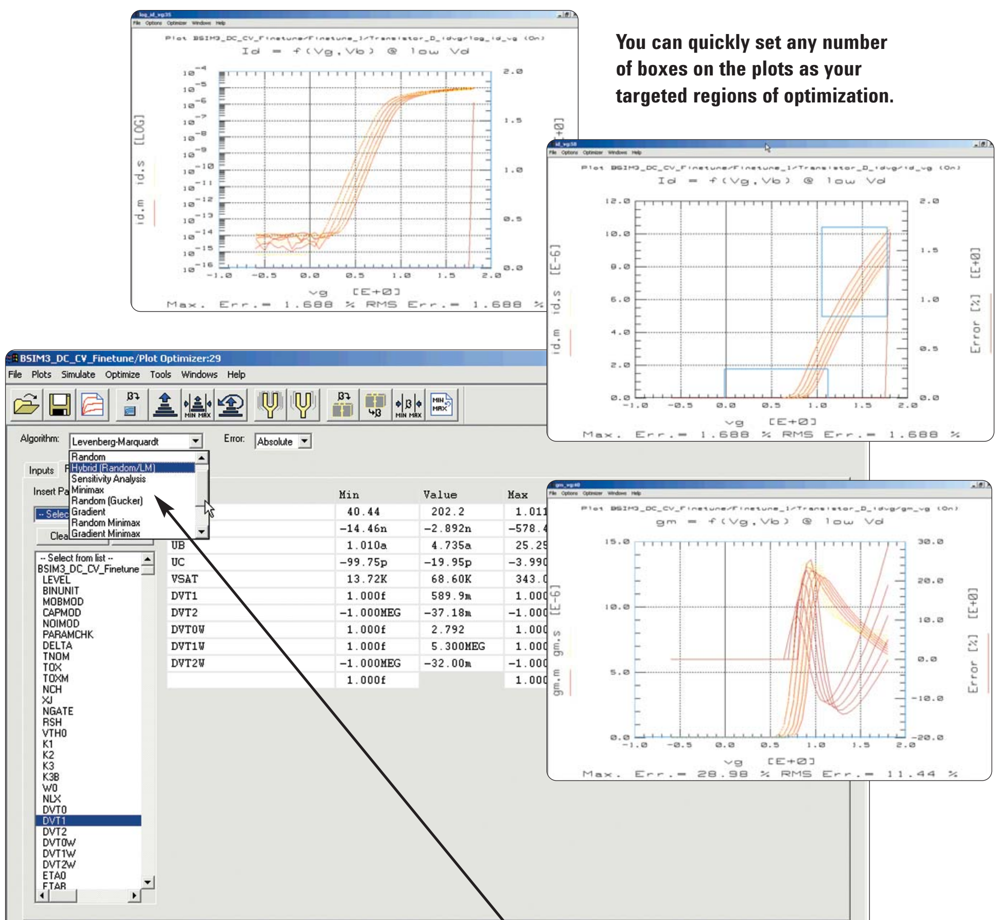


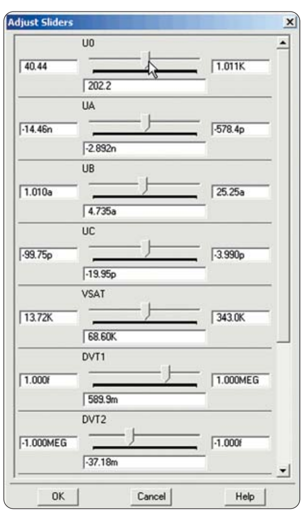
Available extraction, tuning and optimization functions can be added into the group extraction for best results. A group of parameters can be extracted, tuned, or optimized as many times as necessary and in any order to get the best fit.

E for direct extraction
T for tuning
O for optimization

Extract the BSIM4 model with the easy-to-use user interface and configurable extraction/optimization flow.

You can quickly set any number of boxes on the plots as your targeted regions of optimization.





Click open the tuner to manually fine tune parameters.

Choose one of the thirteen optimizers for automatic optimization.

Philips MOS Model 9 with quick extraction and junction capacitance model

Philips MOS Model 9 is a compact MOSFET model suitable for both digital and analog circuit applications. It has single equations covering the variations in current and charge in all device operating regions. All of the important physical effects are modeled, such as substrate body effect, drain-induced barrier lowering, channel-length modulation, and avalanche multiplication. MOS Model 9 is in the public domain and has been implemented within IC-CAP through work jointly carried out by Philips Research Labs, the National Microelectronics Research Center (NMRC) at the University of Cork in Ireland, and Agilent EEsof EDA.

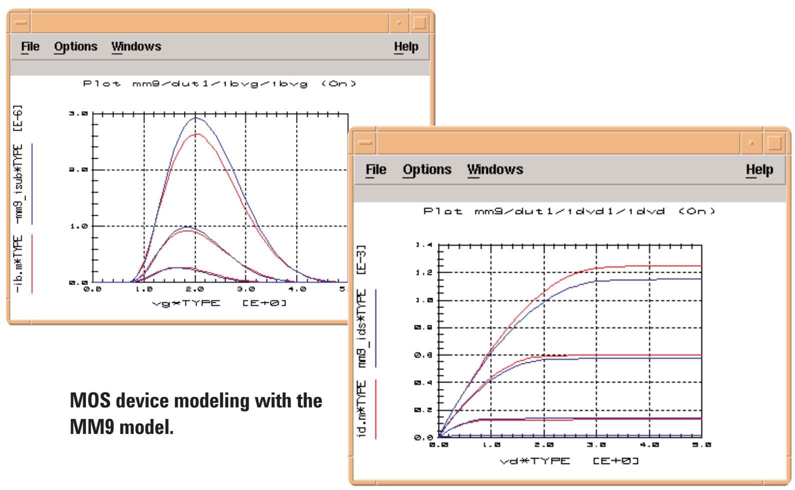
The quick extraction method in IC-CAP requires only minimal optimization for parameter extractions. For example, with the quick extraction method you only need 40 data points to extract a parameter set in contrast to conventional procedures, which typically require 500 to 600 I-V data points for each transistor. This allows you build up a database for statistical modeling more quickly. A junction capacitance model with extraction methodology is also implemented in IC-CAP.

UCB MOS level 2,3 models

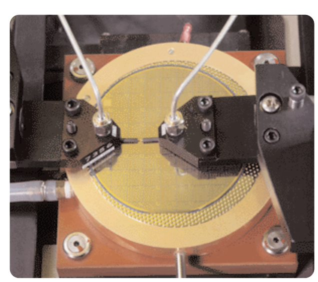
IC-CAP contains extraction routines for the physically-based level 2 and the semi-empirical level 3 MOSFET SPICE models from UC Berkeley. These models have traditionally been used for devices down to one-micron gate widths. The extraction procedure consists of measuring three devices of different geometries: large-channel, narrow-channel, and short-channel. The result is a full set of model parameters that includes channel length and width dependence. If only a single device size is available, you can extract a subset of parameters that fully models the single size.

Agilent EEsof EDA Root MOSFET model

This data-based model uses interpolative spline fitting of S-parameters and CD data arrays over the device's operating range. It has a general approach that can accurately capture device-specific non-linearities. It has highly automated model generation for both digital and analog three-terminal applications.



MOS device modeling with the MM9 model.



BJT Models

IC-CAP BJT models

- BCTM VBIC 1.1.4 BJT model
- Philips MEXTRAM 503 model
- high frequency Gummel-Poon model

BJT model package:

- Gummel-Poon BJT model
- Agilent HF Gummel-Poon BJT model
- Agilent EEBJT2 BJT model

BCTM VBIC BJT model

VBIC is the abbreviation for Vertical Bipolar Inter-Company, a public-domain model developed by the BCTM (Bipolar Circuits and Technology Meeting) consortium. It models quasi-saturation, avalanche, and substrate effects. The latest release includes self-heating effects.

MEXTRAM 503/504 BJT model

MEXTRAM (Most Exquisite Transistor Model) is a public-domain BJT model that has been implemented IC-CAP through work jointly carried out by Philips Research Labs, TU Delft, and Agilent EEsof EDA. It has been used extensively within Philips and has proven to be extremely robust and accurate. MEXTRAM takes into account many physical phenomena associated with modern BJT technologies, including early voltage bias dependency, explicit modeling of inactive regions, current crowding, and conductivity modulation for base resistance and quasi-saturation. Sophisticated modeling, including avalanche multiplication, epitaxial collector layer resistance, and charge storage of advanced high frequency transistors are unique features of MEXTRAM. IC-CAP implementation of MEXTRAM version 503 and 504 has the most efficient and accurate extraction routines and automation features.

HF Gummel-Poon BJT model package

Gummel-Poon BJT model

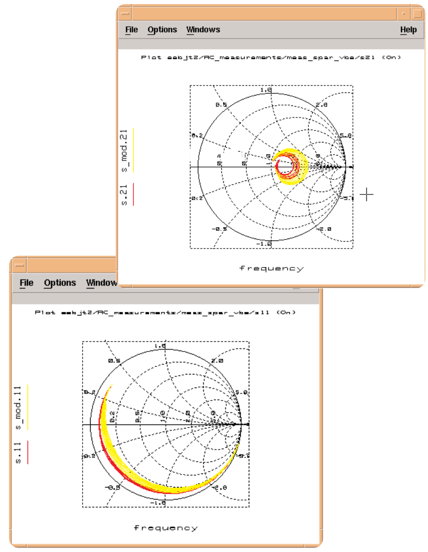
This semi-empirical model has been the industry standard for BJT devices. IC-CAP extracts Gummel-Poon parameters utilizing a combination of DC, capacitance versus voltage (CV), and S-parameter measurements.

Agilent high-frequency Gummel-Poon BJT model

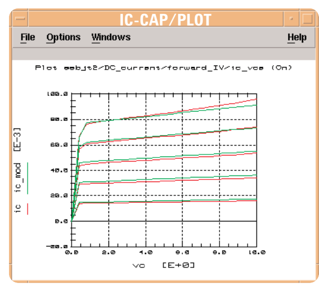
This model includes RF extraction routines for three-terminal NPN BJT devices. CV measurements are replaced with S-parameter measurements, making the junction capacitance extraction more convenient and accurate. Improved methods for extracting ideality, base resistance, and reverse early voltage are also included.

Agilent EEJT2 BJT model

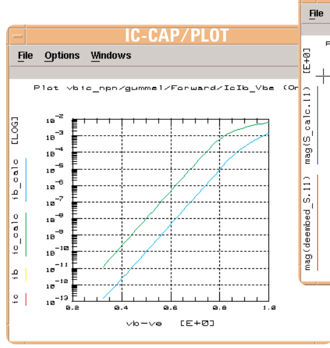
This model is based on the Gummel-Poon model with modifications that improve the accuracy of both AC and DC parameters. For three-terminal, high-frequency, packaged devices, it is highly automated with macros.



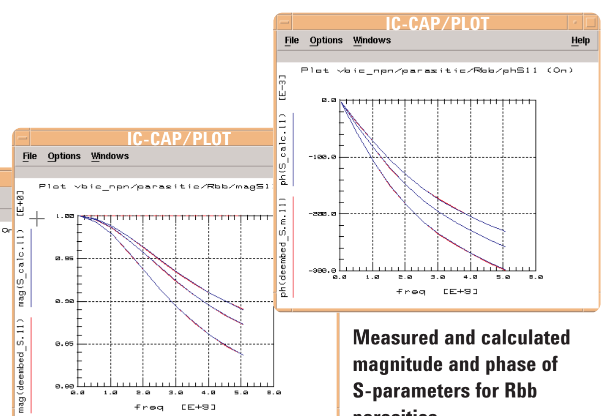
High-frequency modeling of the EEJT2 BJT model.



DC measurement and simulation.



VBIC – measured and calculated ib(vbe).

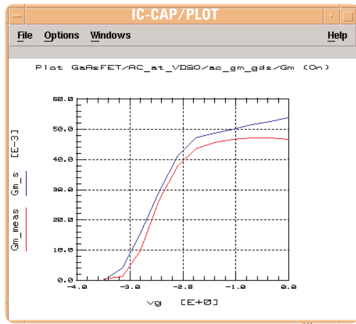


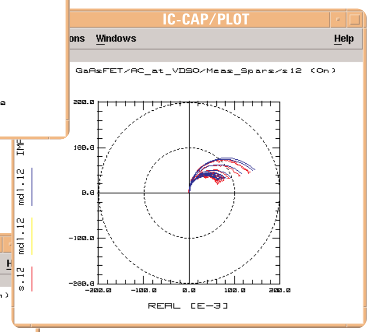
Measured and calculated magnitude and phase of S-parameters for Rbb parasitics.

MESFET Models

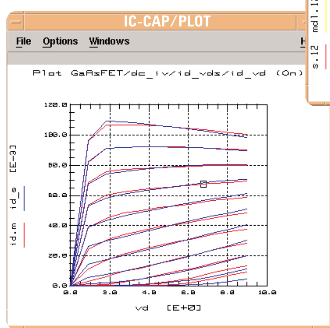
IC-CAP MESFET models

- **MESFET models package:**
- **Curtice Cubic, Curtice Quadratic, and Statz MESFET models**
- **Agilent EEFET3 and EEHEMT1 MESFET models**
- **Agilent Root MESFET/HEMT models**





MESFET modeling for GaAs devices.



Curtice, Statz MESFET models

These models include extraction routines for three popular industry standard MESFET models: the Curtice quadratic, Curtice cubic, and Statz (Raytheon) models. The differences between the three models are in the empirical relationships that describe the DC and AC characteristics of the device. IC-CAP extracts the model parameters from a combination of DC and S-parameter measurements.

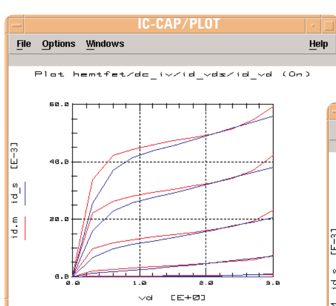
EEFET3/EEHEMT1 models

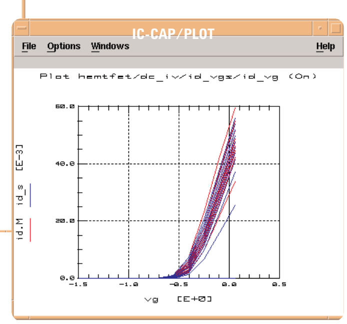
These are empirical, nonlinear models for general GaAs FET applications, including large-signal, three-terminal IC and packaged devices. They accurately model DC and bias-dependent S-parameters, time delay, sub-threshold current, and dispersion of Rds. Also included is the drain current model based on Agilent EEsof EDA original equations and advanced models for Cgs and Cgd, including transcapacitance effects. Static self-heating effects in drain current are also taken into account. The module provides highly automated parameter extraction techniques with package parasitics extracted automatically.

HEMTs are similar to MESFETs but with one distinguishing difference in the behavior of Gm versus Vgs. EEHEMT1 is a superset of EEFET3 and has a set of analytic functions for modeling the Gm compression of a HEMT.

Root MESFET/HEMT models

These are process and technology independent, data-based models for large-signal, three-terminal applications. They model nonlinearities of GaAs FETs and HEMTs, including frequency dispersion. These models are scalable for varying geometries and have automated data acquisition and high-speed model generation.



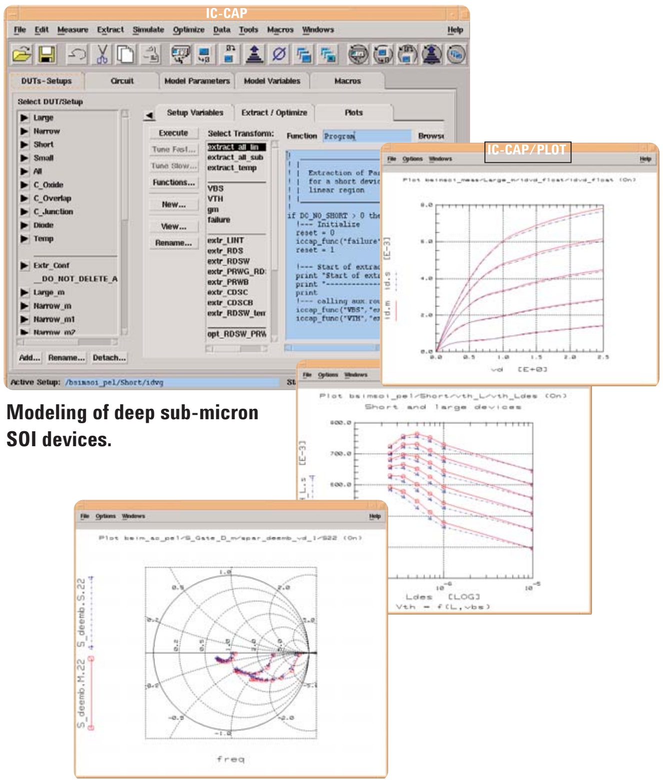


HEMT model I-V results.

Third-Party Models

Parameter extraction language allows flexibility

The unique open and flexible IC-CAP framework enables third-party models to work well with IC-CAP through the parameter extraction language (PEL) capability. Models such as BSIMSOI, EKV 2.6, HISIM, (available from ADMOS) have been exclusively designed to work with IC-CAP.



Modeling of deep sub-micron SOI devices.

Unique high-frequency circuit simulation models

Agilent EEsof EDA has developed several accurate high-frequency models specifically for use with Advanced Design System simulators.

Empirical EE models

- EEFET3 MESFET model
- EEHEMT1 HEMT model
- EEBJT2 BJT model

Benefits to circuit designers

- a high level of accuracy over a range of processes and operating conditions
- extraction of packaged parasitics, which become significant at high frequencies
- a complete set of model parameters, acquired directly from measurements
- highly automated extraction routines for speed and accuracy

Data-based Agilent Root models

A highly automated data acquisition system where DC and S-parameter measurements are taken over the entire operating range of the device, resulting in a generated model table. Data-based modeling plays an important role in the rapid evolution of active device modeling for circuit simulation.

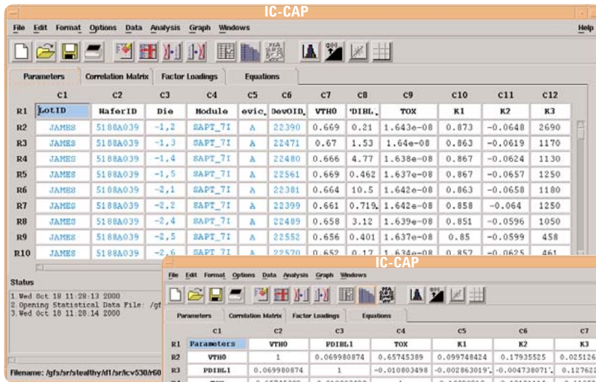
- Root MESFET/HEMT model
- Root MOSFET model
- Root diode model

Benefits of Root models to circuit design groups

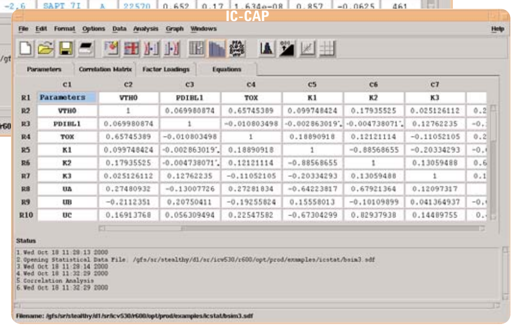
- process and technology independent
- parasitic resistances and inductances are extracted
- direct model generation and high-speed calculations on device data without circuit simulation or optimization
- useful for devices that may not fit existing traditional models

IC-CAP Statistics Package (HP-UX and Solaris Platforms Only)

The IC-CAP statistics package provides conventional parametric analysis and a patented non-parametric boundary analysis that was developed by Agilent EEsof EDA. The parametric analysis includes principal component analysis (PCA), principal factor analysis (PFA), and multiple linear regression.



The spreadsheet interface is intuitive and easy to learn.

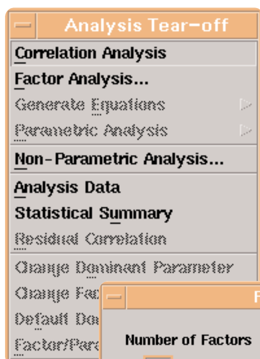


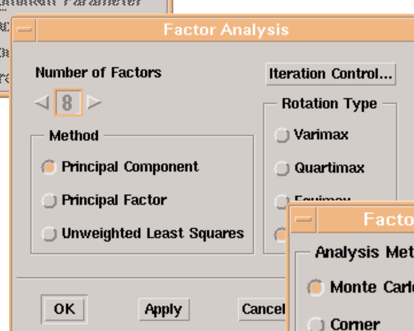
A matrix provides the correlation among parameters.

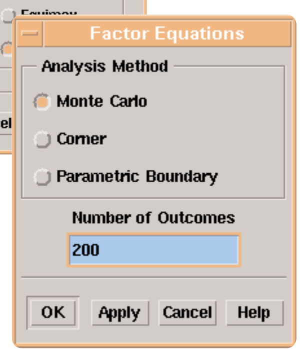
Parametric analysis

With parametric analysis, it is easy to identify the best model parameters to track in electrical test or to build models that predict SPICE parameters or independent factors. These features help circuit designers and process engineers to improve yields and design more robust products. To perform parametric analysis, each parameter distribution is first transformed into a Gaussian distribution. A correlation analysis is performed to determine a correlation coefficient matrix. The correlation coefficients provide a numerical measure of the amount of variation in a variable that is attributable to another variable. To simulate a large number of correlated model parameters, they must be reduced to a smaller number of independent parameters representing the original data set statistical behavior. The main data reduction methods that are used in statistical analysis are PCA, PFA, and unweighted least squares (ULS).

The IC-CAP statistics package automatically generates model files from corner or Monte Carlo analysis. In addition, a new method for generating worst-case model candidates called boundary modeling was introduced in IC-CAP release 5.0.







You can choose principal component, principal factor, or unweighted least squares for factor analysis. You can also choose Monte Carlo, corner, and parametric boundary models.

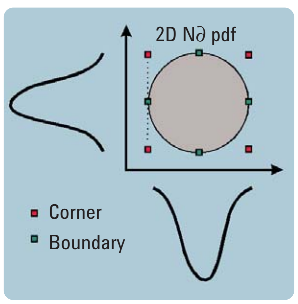
Monte Carlo analysis

Monte Carlo analysis provides an efficient solution to problems involving elements of uncertainty, which are too complex to be solved by strict analytical methods. Instead of calculating all possible combinations, this method uses a small set of randomly generated values to approximate a solution.

IC-CAP Statistics Package – *Continued*

Corner modeling

Corner modeling is used to select worst-case models from a given data set. This method computes the dependent parameters of a data set to arrive at a set of correlated parameters. Traditional worst-case modeling uses corner models. Corner modeling chooses a set of extreme values at the outside of the real multi-dimensional probability density function (PDF) and requires $2n$ simulations for an n-dimensional problem.



Geometric representation of boundary versus corner model.

Parametric boundary modeling

Boundary modeling chooses those extreme values at the boundary of the real multidimensional PDF and only needs $2n$ simulations for an n-dimensional problem. For example, if you chose 10 factors, the number of simulations would be 20, compared to 1024 using corner models. Boundary modeling is an efficient and unique technique to help designers avoid over-designed devices or circuits.

Non-parametric analysis

This non-parametric boundary modeling technique was developed and patented by Agilent EEsof EDA. Unlike other statistical analysis tools, which only handle Gaussian distributions, the non-parametric analysis in IC-CAP uses a new technique to handle any arbitrary data distributions, Gaussian or non-Gaussian, and complete the nominal and boundary models. Non-parametric analysis works for any data from any arbitrary stochastic process. Such processes need not be Gaussian or have any analytical probability density function. The data can be unimodal or multimodal, residing in a single cluster or multiple clusters with no dimensional limitations. In addition, this method does not create any new model parameter set but uses the original data set. Working with the original data avoids the problem of information being lost during data transformation (as with transformation of raw data into a Gaussian distribution).

The non-parametric statistics analysis starts by selecting a nominal point and by choosing boundary points from an arbitrary user-supplied data collection. The nominal point is the point that has the highest estimated local density and the boundary points are those that have the estimated local density greater than some threshold value. The threshold value is determined by specifying the enclosure percentage, which is, under certain circumstances, related to the yield.

All the procedures below can be automated by using IC-CAP parameter extraction language (PEL).

A typical statistical analysis procedure in IC-CAP consists of the following steps:

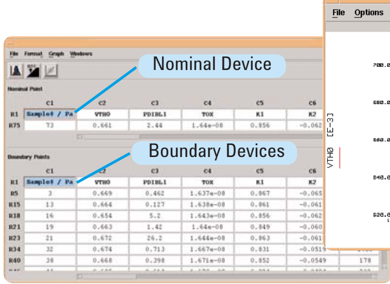
- Import the ASCII formatted database that has measured or extracted data.
- Analyze the data to see if it is a Gaussian distribution.
- Transform data and remove outliers as needed.

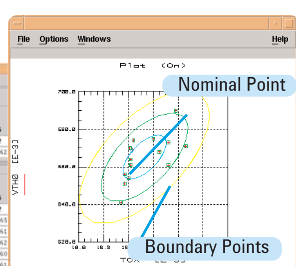
For Gaussian distribution, perform parametric analysis:

- Perform correlation analysis to see the relationship between each pair of parameters.
- Compute factor loadings based on PCA or PFA.
- Build the statistical model relating the model parameters to the independent factors or dominant parameters.
- Generate Monte Carlo, corner, or boundary models.
- Simulate to find the worst-case models.

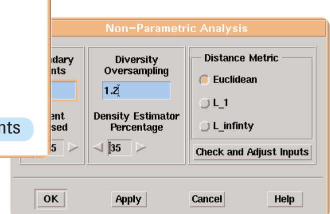
Perform non-parametric analysis:

- Start directly from the measured database or from the non-Gaussian distribution.
- Calculate density measure estimates for all data points.
- Compute nominal and boundary models.





Plot showing the nominal and boundary points.



To perform non-parametric analysis, you can specify the number of boundary points, diversity oversampling, threshold percentage enclosed, and density estimate percentage.

Non-parametric analysis results showing the parameters values of the nominal device (best case) and boundary devices (worst case).

IC-CAP Product Configuration

The IC-CAP component structure includes five major components:

1. IC-CAP software environment
2. analysis module
3. instrument drivers
4. extraction modules
5. statistics package

IC-CAP is available as a complete modeling suite or as individual modules to you the flexibility of choosing the exact modeling capabilities you need.

Agilent 85190A IC-CAP modeling suite

The Agilent 85190A modeling suite provides the basic tools you need to start modeling devices and circuits. The modeling suite consists of the following components:

- 85199A IC-CAP software environment
- 85199B analysis module
- 85199C LCRZ measurement drivers
- 85199D DC measurement drivers
- 85199E AC measurement drivers

The modeling suite lets you set up custom extraction routines, measure data using instrument drivers, analyze results, perform simulations and optimize extracted parameters.

Agilent 85199A IC-CAP software environment

The 85199A is an IC-CAP foundation. It allows you to perform mathematical transforms, customize plots, write macros, create extraction routines using parameter extraction language (PEL) and write user defined functions using C programming language. An extensive function library is available. Also included is the IC-CAP Studio, which allows you to develop graphical user interface.

Agilent 85199B analysis module

The analysis module is the IC-CAP engine (simulator) that provides the ability to simulate device or circuit performance using the built-in SPICE simulators or allows linking to a wide range of external simulators. Links to other simulators can be added using the IC-CAP open simulator interface. Table 2 lists the simulators and optimizers that are included in this module.

Measurement drivers

Measurement drivers allow IC-CAP to control and automate the measurement instruments required to characterize your device or circuit. Table 3 lists the wide range of Agilent Technologies instruments that are supported. Users can add links to other instruments using the IC-CAP open measurement interface.

IC-CAP Product Configuration – *Continued*

Table 2

For PC operating systems only				
Names of simulators	**Version**	**Vendor**	**Local**	**Remote**
HPEESOFSIM	ADS 2005A	Agilent	Yes	No
SPICE3	SPICE3E2	UCB	Yes	No
SPECTRE	5.1.41	Cadence	N/A	Yes
HSPICE	2005.09	Synopsis	Yes	Yes

For UNIX operating systems only				
Names of simulators	**Version**	**Vendor**	**Local**	**Remote**
HPEESOFSIM	ADS 2005A	Agilent	Yes	No
SPICE3	SPICE3E2	UCB	Yes	No
SPECTRE	5.1.41	Cadence	Yes	Yes
HSPICE	2005.09	Synopsis	Yes	Yes
SABER[1]	2005.09	Synopsis	Yes	Yes
ELDO	6.5_2.1	Mentor	Yes	Yes

NOTES **Local.** IC-CAP supports the simulators locally. Both IC-CAP software and the target simulator must run on the same machine.
Remote. IC-CAP supports the target simulators that run on a different machine via remote simulation links. Remote simulation links are available on supported IC-CAP platforms (Solaris, HP-UX, and LINUX operating systems).

1 Saber is supported on HPUX and Solaris only.

IC-CAP Product Configuration – *Continued*

Table 3

Instrument drivers	Instruments supported
Agilent 85199C LCRZ measurement drivers	Agilent 4194 impedance analyzer[1] Agilent 4271 1 MHz dig. capacitance meter[1] Agilent 4275 multi-frequency LCR meter[1] Agilent 4280 2 MHz capacitance meter[1] Agilent 4284 precision LCR meter Agilent 4285 precision LCR meter Agilent 4294A precision LCR meter Agilent E4991A impedance analyzer
Agilent 85199D DC measurement drivers	Agilent 4140 pA meter/DC voltage source[1] Agilent 4141 DC source/monitor[1] Agilent 4142x modular DC source/monitor Agilent 4145x semiconductor parameter analyzer[1] Agilent 4155x semiconductor parameter analyzer Agilent 4156x semiconductor parameter analyzer Agilent E5270 Series parameter analyzer: E5270B, E5272A, and E5273A
Agilent 85199E AC measurement drivers	Agilent E8356A 10 MHz to 3 GHz[1] Agilent E8357A 10 MHz to 6 GHz[1] Agilent E8358A 10 MHz to 9 GHz[1] Agilent PNA: E8362B 10 MHz to 20 GHz, E8363 B 10 MHz to 40 GHz, E8364B 10 MHz to 50 GHz Agilent PNA: E8361A 10 MHz to 67 GHz Agilent N5250A Millimeter-wave PNA, 10 MHz to 110 GHz Agilent Economic PNA: E8801A 3 GHz, E8802A 6 GHz, E8803A 9 GHz Agilent 3577 network analyzer[1] Agilent 8510 network analyzer Agilent 8702 network analyzer[1] Agilent 8719 network analyzer Agilent 8720 network analyzer Agilent 8722 network analyzer Agilent 8753 network analyzer
Agilent 85199F time domain measurement drivers	Agilent 54121T-54124T digitizing oscilloscopes[1] Agilent 54510 digitizing oscilloscopes[1] Agilent 54750 TDR oscilloscope[1] Agilent 8130 pulse generator[1] Agilent 8131 pulse generator[1]
Agilent 85199G noise measurement drivers	Agilent 35670A dynamic signal analyzer Agilent 85199H
Agilent wafer prober command sets included in Agilent 85199A	ElectroGlas 1034x ElectroGlas 2001x TSK APM3000A Cascade Summit 10000 Cascade Summit 12K
Switching matrix drivers included in Agilent 85199A	Agilent 4085A Agilent 4085B Agilent 4089A[1] Agilent E5250A

1 These instruments are no longer available from Agilent. The drivers are no longer supported with modifications or enhancements.

IC-CAP Product Configuration – *Continued*

Agilent 85199J IC-CAP statistics package: parametric and non-parametric analysis (requires the IC-CAP software environment). Available on UNIX version only.

IC-CAP extraction modules and model generators

The modules listed in Table 4 include all of the measurement setups, mathematical transforms, extraction routines, and documentation required to perform extractions with IC-CAP.

Table 4

			Drivers required			Simulator compatibility	
Device product	**Type number**	**Models included**	**LCRZ**	**DC**	**AC**	**UCB SPICE**	**ADS**
MESFET & HEMT	85191A	Agilent Root MESFET/HEMT		✔	✔		✔
	85192A	Curtice Cubic					
		Curtice Quadratic		✔	✔	✔	✔
		Statz-Pucel (Raytheon)		✔	✔	✔	✔
		EEFET3		✔	✔		✔
		EEHEMT1		✔	✔		✔
BJT	85193A	Gummel-Poon	✔	✔	✔	✔	✔
		High-frequency Gummel Poon			✔	✔	✔
	85193C	Agilent EEBJT2					
		MEXTRAM 503/504	opt	✔	✔		✔
	85193D	VBIC	opt	✔	✔		✔
MOSFET	85194H	UCB MOS level 2	✔	✔		✔	✔
		UCB MOS level 3	✔	✔		✔	✔
		High-frequency MOS level 3	✔	✔	✔	✔	✔
	85194B	Root MOS		✔	✔		✔
	85194E	UCB BSIM3	✔	✔		✔	✔
	85194J	MOS Model 9	✔	✔			✔
	85194K	UCB BSIM4	✔	✔	✔	✔	✔
Diode	85195A	Agilent Root diode		✔	✔		✔
Noise	85195B	1/f noise		✔		✔	✔

Licensed software

Each IC-CAP module is available in two license versions:

1. A node-locked version allowing the software to execute only on a single workstation or a PC.
2. A network-licensed version for execution on multiple workstations or PCs on a network, allowing various workgroups to share the software.

Both licenses use the FLEXlm license management system. These two license options can be mixed freely. For example, a node-locked license of an instrument driver package can reside on a workstation or PC in the lab, while a network license for the analysis module can be shared among a group of engineers for data analysis.

World-Class Support and Training

Agilent EEsof EDA is committed to helping you achieve success with IC-CAP through customer education courses, technical support, and custom solution services.

To help you begin using IC-CAP quickly and productively, a comprehensive, three-day course is offered at various locations, including the Agilent EEsof EDA facility in Santa Rosa, California, USA.

A support contract also includes automatic software updates, literature, and documentation to bring you the latest product enhancements and features.

Contact Information

All Agilent Eesof EDA products:
www.agilent.com/find/eesof

IC-CAP device modeling:
www.agilent.com/find/eesof-iccap

World Wide Web

Our Agilent EEsof EDA World Wide Web includes a special Support Web area for downloadable patches, defects and solutions, and online technical support. In addition, Agilent EEsof EDA gives you access to other services, including:

- news and events
- product information and on-line demos
- product applications and examples
- online product documentation
- customer training classes
- online and telephone technical support
- knowledge center with application examples and users' discussion forum

For more information about Agilent EEsof EDA, visit:
www.agilent.com/find/eesof

For more assistance with your test and measurement needs visit:
www.agilent.com/find/contactus

Phone or Fax

United States:
(tel) 800 829 4444
(fax) 800 829 4433

Canada:
(tel) 877 894 4414
(fax) 800 746 4866

China:
(tel) 800 810 0189
(fax) 800 820 2816

Europe:
(tel) 31 20 547 2111

Japan:
(tel) (81) 426 56 7832
(fax) (81) 426 56 7840

Korea:
(tel) (080) 769 0800
(fax) (080)769 0900

Latin America:
(tel) (305) 269 7500

Taiwan:
(tel) 0800 047 866
(fax) 0800 286 331

Other Asia Pacific Countries:
(tel) (65) 6375 8100
(fax) (65) 6755 0042
Email: tm_ap@agilent.com
Contacts revised: 05/27/05

Product specifications and descriptions in this document subject to change without notice.

Printed in USA, March 20, 2006
5965-7742E

Agilent Technologies