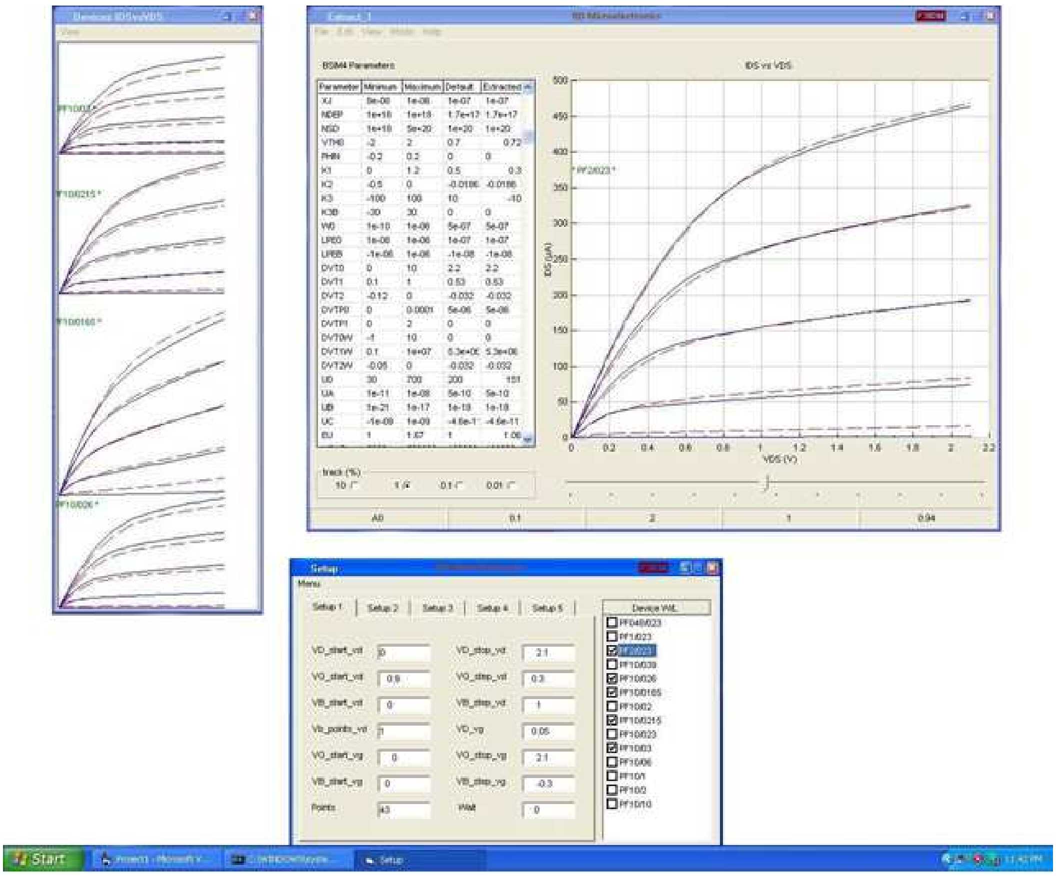
Product description (v.1.0) 2006©

CMOS Transistor Characterization Tool

Software



Research and Development in Microelectronics

Dr. Kamel Ayadi

The MOS characterization tool

1. Which technical problem is to be solved by the Software?
2. How has this problem been solved up to now?
3. In what manner does the Software solve the technical problem indicated (advantages)?
4. What is the Software step?

1. The proposed parameter extractor software is able to extract precisely the parameters of MOS transistor by using the latest version of physical equations of deep sub-micron technology. Berkeley University provides the C-code of the physical equations named BSIM for worldwide use and charge free. The download of BSIM C-code is possible from the web address http://www-device.eecs.berkeley.edu/-bsim3/

The parameter extractor software controls and interacts with the PSpice simulator and simulates the MOS transistor by using the C-code BSIM and stimulus control. The presented extractor software contains also test routines for measuring MOS transistor (I_{ds} vs V_{ds}, I_{ds} vs V_{gs}, ...).

Best reference to the theoretical details of the MOS parameters and the characterization curves is in the user's manual of HSpice and BSIM. The simulator Titan of Siemens AG is also supported.

2. When the technology of MOS transistor is moving towards down scale transistor, the number of parameters of the transistor is heavily increasing. BSIM-v3 that was released in December 1996 has about 160 parameters. BSIM-v3 was implemented for parameter extraction of sub micron MOS transistor. BSIM-v4 was released in April 2001 with about 600 parameters, and it was implemented to extract the parameters of sub 0.1 µm MOS transistor.

The two commercial existing extractor tools, UTMOST of Silvaco International and IC _CAP of Agilent Technologies, use BSIM as the engine. They have made also graphical windows to load the measured curves (I_{ds} vs V_{ds}, I_{ds} vs V_{gs}, ..) as well as the simulated curves, all run on Sun stations. Our extractor tool does the same but run on PC computer and under Windows.

The user has to manipulate the parameter values to fit the simulated curves to the measured one. When the parameters are extracted, they are collected in a file known as Model file. The designers of integrated circuits use the model file of the specific technology and simulate their digital and analog circuits.

Such software for parameter extraction, presented here, running on PC platform is not yet available on the market. Also, the licenses from the commercial IC-CAP and UTMOST softwares

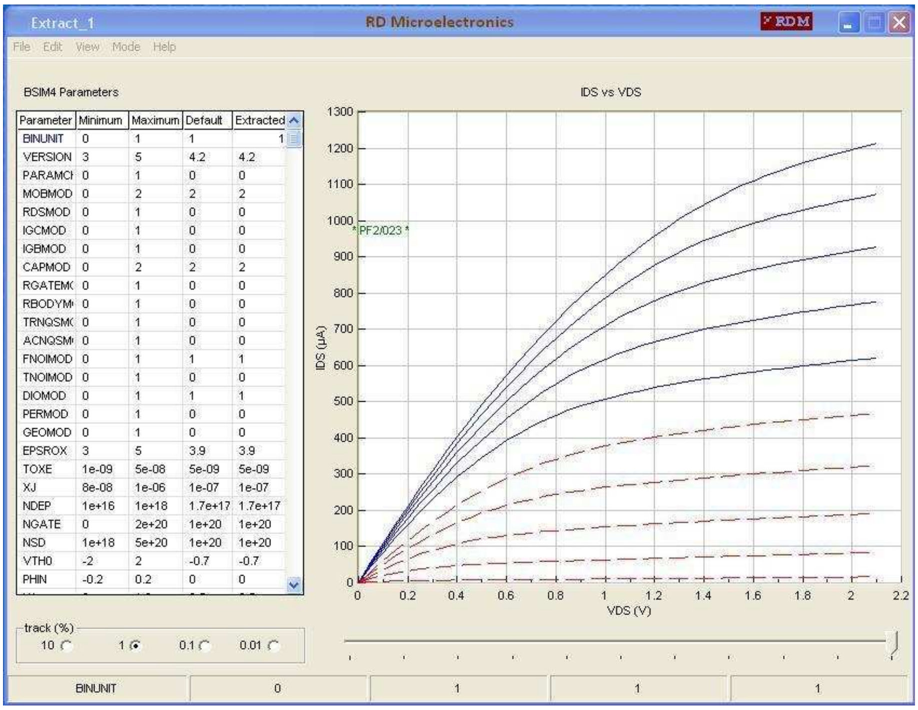


Figure 1: Main graphical window of the parameter extractor software and its menus.
The dashed lines are the measured curves I_{ds} vs V_{ds} of MOS transistor.
The solid lines are the simulated curves in BSIM4 with this software.

are expensive, UTMOST costs about 50 000 € and IC-CAP about 500 000 €, but ours costs 1 000€.

3. The present parameter extractor extracts the parameters of MOS transistor. It uses the C-code of BSIM as the engine, PSpice as the simulator, and graphical windows to display the measured and simulated curves (I_{ds} vs V_{ds}, I_{ds} vs V_{gs}, ..) together, and all run on PC station (Windows XP and Vista). This software simulates and displays immediately the simulated curves with no significant time delay. Upon the user modify the parameter values, the parameter extractor stores them in a model file, activates PSpice and controls it with a stimulus.

PSpice inserts the parameter values into BSIM Code and compiles. PSpice has a compilation time in the range of µs and generates files of data. The rest is to display those new simulated curves and display them with the measured ones, as shown in Fig. 1.

The display of the data in curves is with a complete operation time of about one second, compilation and display. It is also the same operation time for the commercial softwares, despite they run on high speed and multiprocessor SUN station. In addition, the proposed parameter extractor has many features that make it flexible for the user. Other new ideas can be implemented in the software without any problem or major limitation, but the basic function of the software is described here. The demonstration and presentation are strong approval of the capability of this software.

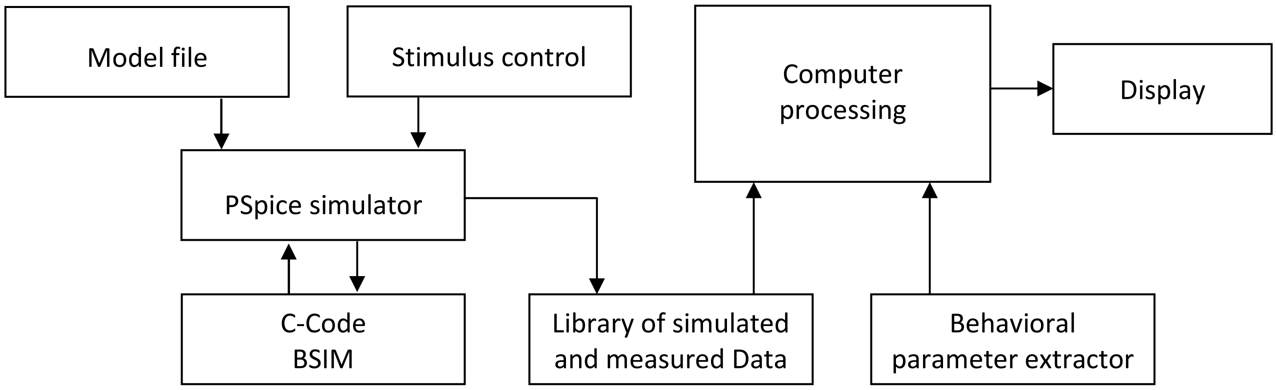


Figure 2: Block diagram of the parameter extractor tool.

4. The software has a main graphical window, as shown in the Figure 1. This main graphical window contains a table that is used to display the parameters (parameter name, minimum values, maximum values, default values, and extracted values). It has also a graphical display to display together the measured and simulated curves. It has also a slider, but not limited to one only, and a status-bar. The slider and the status-bar are helpful to the user. It has also many menus and submenus to operate and activate their functions.

When the user loads the parameter file, the software activates PSpice and links the path of the stimulus control file to PSpice shell window. The stimulus itself has a link to a model file and has transistor description (type, size, ...) and other PSpice commands and syntaxes to perform the simulation accordingly. Titan simulator of Siemens AG can replace PSpice in this extractor tool.

The stimulus indicates which BSIM version is being used and other specific PSpice parameters. The diagram of the parameter extraction system is described in Fig. 2. The code of the Tool is indicated in Fig. 2 by a behavioral parameter extractor.

At the beginning of the extraction, the model file contains the default values of the loaded parameters of BSIM. All parameters will be used to simulate the transistor, but not all of them have to be extracted. Many parameter values remains defaults since the default values are calculated and based of physics and technology, such as layer thickness, material mobility, ... The user has to manipulate the values of the parameter targets only.

In the manual mode operation, the user clicks from the table on the name of the parameter being extracted. The entire row becomes sensitive to any movement of the slider and turns to a different color. Also the data of the row is clearly displayed in the status-bar. The minimum and the maximum of the slider are those of the selected parameter, and the slider is positioned initially on the default parameter value. The user can use the computer mouse or the left and right arrows of the computer keyboard to move the slider left or right, and then track the

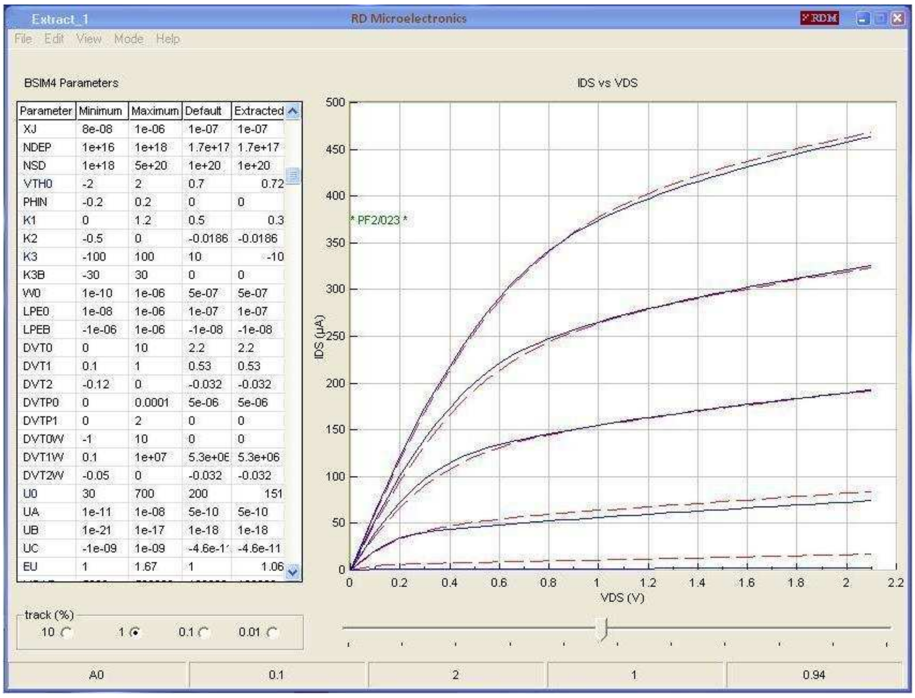


Figure 3: Main graphical window of extractor software steps of extraction.
The simulated curves I_{ds} vs V_{ds} are fitting the measured curves.

parameter value. The slider is set always on focus and there is no need to select it.

When the slider moves, the extracted value of the parameter is changed in the table and the status-bar. The parameter extractor software opens the model file and copies the new extracted parameter values from the table. It activates then PSpice and links it to the stimulus to perform a new simulation based on the new entered parameter values. When PSpice completes successfully the simulation and provides the data result in files, the parameter extractor displays the data in curves on the display and waits for any new slider movement to proceed with new operation.

The user manipulates his parameters one after the other and looks to the simulated curves if they fit the measured curves. The extraction steps are based on technique and experience since the parameters react differently in the zones sub-threshold, threshold, inversion, strong inversion, and saturation. The optimum extraction time is however not related to the speed of the software only, but also on the way we select the parameters and track their values.

There are click options below the table, they are used to control the movement of the slider. When the simulated curves are closely fitting the measured curves with a track of 1 %, the user can continue tracking softly on the parameter values for precise extraction by selecting the track of e.g. 0.1% or 0.01%.

For indication, a track of 0.01% is a track of the forth digit.

Example: the value is 3.7694, after 0.01 % track it becomes 3.7695

Text Browser

File

C:\C_FOU_\Output\Model_Finger.txt

```
.MODEL PFTK NMOSBS42
+ VERSION =4.2 BINUNIT = 1  PARAMCHK = 0  MOBMOD = 2
+ RDSMOD = 0  IGCMOD = 0  IGBMOD = 0  CAPMOD = 2
+ RGATEMOD = 0  RBODYMOD = 0  TRNQSMOD = 0  ACNQSMOD = 0
+ FNOIMOD = 1  TNOIMOD = 0  DIOMOD = 1  PERMOD = 0
+ GEOMOD = 0  EPSROX = 3.9  TOXE = 5e-09  XJ = 1e-07
+ NDEP = 1.7e+17  NSD = 1e+20  VTH0 =0.68 PHIN = 0
+ K1 =0.58 K2 = -0.0186  K3 =12 K3B = 0
+ W0 = 5e-07  LPE0 = 1e-07  LPEB = -1e-08  DVT0 =2.1
+ DVT1 =0.56 DVT2 = -0.032  DVTP0 = 5e-06  DVTP1 = 0
+ DVT0W = 0  DVT1W = 5.3e+06  DVT2W = -0.032  U0 =144.21
+ UA = 5e-10  UB = 1e-18  UC = -4.6e-11  EU =0.992
+ VSAT = 100000  A0 =1.02 AGS = 0  B0 = 0
+ B1 = 0  KETA = -0.047  A1 =0.94 A2 = 1
+ WINT = 0  LINT = 2e-08  DWG = 0  DWB = 0
+ VOFF = -0.08  VOFFL = 0  MINV = 0  NFACTOR = 1
+ ETA0 = 0.08  ETAB = -0.07  DSUB = 0.56  CIT = 0
+ CDSC = 0.00024  CDSCB = 0  CDSCD = 0  PCLM = 1.3
+ PDIBLC1 = 0.39  PDIBLC2 = 0.0086  PDIBLCB = 0  DROUT = 0.56
+ PSCBE1 = 5e+09  PSCBE2 = 5e-06  PVAG = 0  DELTA = 0.01
+ FPROUT = 0  PDITS = 0  PDITSL = 0  PDITSD = 0
+ RDSW = 1200  RDSWMIN = 0  PRWG = 0  PRWB = 0
+ WR =1.1 ALPHA0 = 0  ALPHA1 =-0.06 BETA0 = 30
+ AGIDL = 0  BGIDL = 2.3e+09  CGIDL = 0.5  AIGBACC = 0.43
+ BIGBACC = 0.054  CIGBACC = 0.075  NIGBACC = 1  AIGBINV = 0.35
+ BIGBINV = 0.03  CIGBINV = 0.006  EIGBINV = 1.1  NIGBINV = 3
+ AIGC = 0.054  BIGC = 0.054  CIGC = 0.075  AIGSD = 0.43
+ BIGSD = 0.054  CIGSD = 0.075  DLCIG = 2e-08  NIGC = 1
+ POXEDGE = 1  PIGCD = 1  NTOX = 1  TOXREF = 3e-09
+ XPART = 0  CGSO = 2e-10  CGDO = 2e-10  CGBO = 1e-12
+ CGSL = 0  CGDL = 0  CKAPPAS = 0.6  CKAPPAD = 0.6
+ CF = 1.1e-10  CLC = 1e-07  CLE = 0.6  DLC = 2e-08
+ DWC = 0  NOFF = 1  VOFFCV = 0  ACDE = 1
+ MOIN = 15  DWJ = 0  JSS = 0.0001  JSD = 0.0001
+ CJS = 0.0005  CJD = 0.0005  MJS = 0.5  MJD = 0.5
+ MJSWS = 0.33  MJSWD = 0.33  CJSWS = 1e-10  CJSWD = 1e-10
+ CJSWGS = 1.5e-10  CJSWGD = 1.5e-10  MJSWGS = 0.33  MJSWGD = 0.33
+ PBSWS = 0.8  PBSWD = 0.8  PBSWGS = 0.8  PBSWGD = 0.8
+ TNOM = 85  UTE = -1.3  KT1 = -0.3  KT1L = 0
```

Figure 4: The generated model file that contains the extracted parameters.

Many other options are implemented, such as the simultaneous display of simulated curves of different sized transistors in another graphical window called Devices (submenus under Palette menu). Other options can easily be implemented; one has to imagine their functions and their purposes.

In the Fig. 3 is the displayed curves of drain current versus drain source voltage (I_{ds} vs V_{ds}) with a variation of the gate voltage. These curves are initially obtained based on the default values of BSIM-v4, as shown in Fig. 1. After few steps of parameter extraction, the curves are very closely fitting the measured curves in few minutes of complete user manipulation, as shown in Fig. 3.

After the parameter extraction is achieved, the user selects the submenu Save As under File menu, and provides a model filename, so that the software saves the model file, shown in Fig.4.

Research and Development
in Microelectronics

Product categories:

Instruments

- SBM is a spectrometer for measuring the brightness of the monitors and flat displays.
- FLT is an instrument for measuring the factor of light transmitted into glass. Typical use: qualification of car and aircraft windscreens).

Consumer electronics

- House security system.
- Electronic watches and alarm clocks.

Electronic for automotive industry

- Crash system.
- Parking and alarm system equipped with TFT display, cameras and ultrasonic sensors.

Wireless

Network operating system, as big as an auto radio.

Device for satellite

Surveillance system against projectile moving at a velocity of up to 1000 kM/h.

Fiber to the Home networking

A prototype of 128 Gbit/s/chip optical networking system, for low cost fiber optic network by using short-wavelength laser light and CMOS photoreceivers. It is a project and we are looking for sponsors and investors.

Navigation control for military

Micro-controller base control system for small motors and rotors.

IT, Software tools and Measurement routines

MET is a MOS extractor tool for the characterization of the transistors and the extraction of their technology parameters. BSIM3 and 4 are implemented in MET. We also offer measurement routines to control instruments and wafer probe-stations, so that the measurement of transistors and ICs will be fully automatic. All runs on PC platform.

Technical Support

- Hotline and per e-mail for service and support: support@RDMicroelectronics.com
- Service and Maintenance Contracts.
- Component Testing and Repair.

Consulting and Service

- To the costumers, we design and make layout of CMOS and BiCMOS integrated circuits as well as microchips with Cadence and Mentor Graphics tools.
- Development of electronic devices according to specifications and timetable of our clients.
- Prototyping new ideas and conducting research in Microelectronics and Opto-electronics, in conjunction with our partners and research centers.

RD Microelectronics
House Address:
RingStr. 42
82110 Germering (near Munich)
Germany.
Tel. ++49-160-92088558

Post Address:
Postfach 1915
82103 Germering
Germany.
E-Mail: info@RDMicroelectronics.com
Webpage: www.RDMicroelectronics.com

Steuernummer: 117-201-91069
UStId-Nr. DE250943369