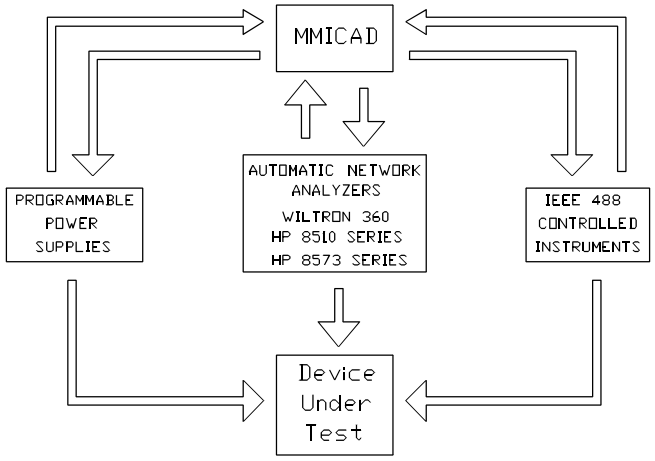
Computer Aided Testing with MMICAD

Series #4: Automated Data Acquisition from an Automatic Network Analyzer (ANA) and Programmable Power Supplies



RF and microwave engineers involved in modelling and characterization often require large number of S-Parameter files of a device as a function of applied bias. For example, modelling bipolar transistors as functions of base and collector bias, field effect transistors as functions of gate and drain bias, and characterizing varactor diodes. Using MMICAD's **Variational Analysis** mode, one can automatically acquire S-Parameters from an ANA while sweeping the DC bias of programmable power supplies in pre-determined steps and ranges. The data will be stored in auto-incrementing files unattended.

This application note provides a step-by-step description of how to automate Computer-Aided-Testing with MMICAD for acquisition of data.

Example

Automation of the following test specifications is desired:

ANA: WILTRON 360

Frequency Range: 1-10 GHZ with steps of 0.25 GHZ

DC Power Supplies: KEITHLEY Models 236 and 237

Device Under Test: MESFET

Fixed drain Bias: +4 V

Varying Gate Bias: Start= -2.0V End=+0.2V Step=0.1V

Total # of Tests: $Number\ of\ Tests = \frac{End - Start}{Step} + 1$ =23 Tests

Filenames: FETSETnn.S2P, nn is an auto-incrementing number
where:
Filename Prefix: FETSET
Filename Extension: S2P
Auto-increment nn: 1 to 23, corresponding to gate biases -2V to +.2V in steps of 0.1V respectively

Other data: Measure the drain and gate currents for each test, and paste into data files.

Note: The reader should first refer to application notes 24-26 for (1) configuration and setup of MMICAD for C.A.T., (2) configuration of the network analyzer for the required frequency range, and (3) syntax of the IEEE-488 commands for sourcing voltages and acquiring currents from the programmable DC power supplies.

Step #1: Customizing auto-incrementing filenames for Variational Analysis

(a) Navigate to "**E:Defaults**" of the "**Settings**" Menu in MMICAD and press enter.

(b) To customize the directory where the data files will be stored, select the "**Default MMICAD Data File Directory**" and type the desired drive and path names; for example, \MMICAD\WORKING.

(c) Select "**Prefix for Sequential Text (ASCII) Files**" and type FETSET as a prefix.

(d) Select "**Extension for Sequential Text (ASCII) Files**" and type S2P as an extention.

(e) Select "**Starting value for Sequential Text (ASCII) Files**" and type 1.

(f) Select "**Automatically Save in Tune and AutoTune Mode**" and type Y.

(g) Select "**Save Values and Exit**" and press enter.

Step #2: Circuit File Construction

The construction of the circuit file requires calls to the ANA via the **FILES** block, calls to the programmable power supplies via the **IEEE** block, setting up the variable bias with the **PARAM** block, required frequency sweep with the **FREQ** block, and the output data files with the **OUT** block.

(a) FILES Block Syntax

<ANAcode> <Network> <# of Data Points> <nP>

<ANAcode> is one of two special code words recognized by MMICAD, they are **WILTRON** for Wiltron 360 ANA, and **HPANA** for HP 8510, 8720, 8753, or 8702 ANAs.

<Network> is any valid network name

<# of Data Points> should be equal or larger than number of frequencies swept by the ANA

<nP> specifies the number of ports for the data

(b) VAR Block Syntax

The biases for the drain and gate are defined in the VAR block. The fixed bias variable is given a constant value, and the varying bias is set equal to **PARAM**.

(c) IEEE Block Syntax

Five control statements are used: **WRITE, READ, PAUSE, TRIGGER,** and **LOCAL**.

(i) WRITE Control Statement Syntax:

[WRITE] <Device Name> <Write String> <Variable> [<Mask>]

where:

[WRITE] indicates a write operation of a variable on the bus. This keyword is optional. If the first word on the line is none of **WRITE, READ, PAUSE, TRIGGER,** and **LOCAL,** MMICAD interprets the line as a **WRITE**.

<Device Name> is the device name as defined in the National Instruments IEEE-488 configuration program IBCONF.EXE.

<Write String> is a string of characters enclosed in quotes. This contains the ASCII string to be sent to the **<Device Name>**, followed by a comma and either %f or %i depending on whether a floating point or integer variable is to be used.

<Variable> is the name of a global variable previously defined in the circuit file's VAR block.

[<Mask>] is an integer constant used by MMICAD to check the status byte of the instrument. Once the string is sent to the device, MMICAD will read the status byte from it; this byte is logically ANDed with the mask value. If the value is nonzero, MMICAD interprets this as a device error and will stop analysis and display an error message. This keyword is optional.

Example WRITE DEV14 "VSET1, %f" VD 32

(ii) READ Control Statement Syntax:

READ <Device Name> <Read String> <Variable>

where:

READ indicates a read operation into a variable on the bus.

<Device Name> is the device name as defined in the National Instruments IEEE-488 configuration program IBCONF.EXE

<Read String> is a string of characters enclosed in quotes. This contains an ASCII string, followed by a comma and either %f or %i depending on whether a floating point or integer variable is to be used. The ASCII string will be printed in a result file besides the value returned into %f or %i from the instrument.

<Variable> is the name of a global variable previously defined in the circuit file's VAR block. MMICAD will store the value read from the device into the **<Variable>**.

Example READ DEV15 "COLLECTOR CURRENT:, %f" IC

(iii) PAUSE Control Statement Syntax:

PAUSE <String>

where

PAUSE is used to pause the operation of MMICAD waiting for a key press.

<String> when a **PAUSE** is executed, **<String>** is displayed on the status line of the analysis window.

Example PAUSE "CONNECT THE DEVICE"

(iv) TRIGGER Control Statement Syntax:

TRIGGER <Device Name>

TRIGGER is used to trigger **<Device Name>**

Example TRIGGER DEV14

(v) LOCAL Control Statement Syntax:

LOCAL <Device Name>

The **LOCAL** command is used to return **<Device Name> to local.**

Example LOCAL DEV14

```
MMICAD 5.0  LINEAR ANALYSIS AND CIRCUIT DESIGN                OPTOTEK LTD
FILE NAME: APP27.CKT    AUTHOR: MMICAD Authors                04/29/1992
 ** AUTOMATED COMPUTER-AIDED-TESTING of a MESFET as function of Gate Bias **

 Using VARIATIONAL ANALYSIS, MMICAD Acquires and automatically saves
 S-Parameters from an ANA while Controlling two Programmable DC Supplies
 Network Analyzer : Wiltron 360, calibrated between 1 to 10 GHZ
Control Device #1: "SMU236A" KEITHLEY DC Power Supply for Gate Bias
Control Device #2: "SMU236B" KEITHLEY DC Power Supply for Drain Bias
FILES
   WILTRON MESFET 502 2P      ! Extract MESFET S-Parameters from Wiltron 360
VAR
   VG=PARAM                   ! Gate Bias is swept as defined in PARAM block
   VD=4                       ! Fixed Drain Bias
   ID=1                       ! Initial Drain Current Value
   IG=1                       ! Initial Gate Current Value
IEEE
   SMU236A "G4,2,0"           ! Command KIETHLEY #1 to measure current
   SMU236B "G4,2,0"           ! Command KEITHLEY #2 to measure current
   SMU236A "B%f,0,5X" VG 32   ! Source VG bias and wait 5 milli-seconds
   SMU236B "B%f,0,5X" VD 32   ! Source VD bias and wait 5 milli-seconds
   READ SMU236A "IG=:" IG     ! Read IG from KEITHLEY #1
   READ SMU236B "ID=:" ID     ! Read ID from KEITHLEY #2
FREQ
   SWEEP  1.0  10   0.25
PARAM
   SWEEP  -2.0  0.2  0.1     ! VG Sweep
OUT
   MESFET SPAR SDATA          ! Display and Save S-Parameters
LABEL
!
FREEZE ON                     ! Output for VG=-0.3V is pasted below
!   FILE: C:\MMICAD\WORKING\FETSET18.S2P
!
!      File: C:\MMICAD\WORKING\APP27.CKT
!   SMU236B -> G4,2,0
!   SMU236A -> G4,2,0
!   SMU236A -> B-0.300000,0,5X
!   SMU236B -> B4.000000,0,5X
!   SMU236A <- THE GATE CURRENT : -000.003E-03
!   SMU236B <- THE DRAIN CURRENT: +049.566E-03
#  GHZ S MA R 50.00
!   MMICAD -- Tue May 05 09:28:46 1992
!   CIRCUIT: MESFET
! FREQ      --- S11 ---          --- S21 ---          --- S12 ---          --- S22 ---
!              MAG     ANG         MAG     ANG         MAG     ANG         MAG     ANG
1.000      0.977  -17.900    3.742   165.20      0.0202   75.400     0.712    -9.000
1.250      0.969  -22.111    3.690   162.12      0.0248   71.478     0.706   -11.011
1.500      0.956  -25.867    3.614   159.20      0.0270   67.600     0.699   -12.467
1.750      0.956  -29.600    3.575   156.70      0.0312   69.500     0.699   -14.200
2.000      0.954  -33.547    3.539   153.90      0.0357   67.778     0.700   -16.073
2.250      0.952  -37.461    3.507   151.03      0.0401   66.247     0.698   -18.037
2.500      0.948  -41.600    3.462   147.90      0.0445   63.400     0.693   -20.100
2.750      0.940  -45.433    3.401   145.16      0.0477   60.324     0.687   -21.926
3.000      0.933  -49.278    3.351   142.36      0.0515   58.189     0.681   -23.856
3.250      0.923  -53.162    3.291   139.26      0.0549   55.787     0.674   -25.687
3.500      0.910  -56.511    3.212   136.82      0.0580   53.178     0.666   -27.344
3.750      0.900  -59.442    3.135   134.60      0.0605   51.219     0.661   -28.678
4.000      0.897  -62.400    3.076   132.10      0.0626   49.900     0.659   -29.900
4.250      0.894  -65.831    3.031   129.60      0.0659   47.851     0.657   -31.747
4.500      0.885  -69.167    2.971   127.07      0.0689   45.389     0.651   -33.467
4.750      0.876  -72.075    2.899   124.71      0.0713   42.800     0.645   -35.050
5.000      0.865  -74.733    2.829   122.61      0.0722   40.822     0.637   -36.000
5.250      0.859  -77.310    2.769   120.59      0.0729   39.746     0.634   -36.993
5.500      0.857  -79.900    2.720   118.50      0.0747   39.100     0.634   -38.500
5.750      0.855  -82.581    2.668   116.32      0.0770   37.718     0.631   -40.118
6.000      0.852  -85.078    2.614   114.31      0.0790   36.944     0.629   -41.289
6.250      0.849  -87.737    2.559   112.22      0.0818   36.075     0.629   -42.687
6.500      0.844  -90.267    2.504   110.23      0.0838   34.500     0.627   -44.267
6.750      0.838  -92.711    2.450   108.30      0.0857   32.667     0.622   -45.767
7.000      0.832  -95.100    2.396   106.40      0.0880   31.000     0.619   -47.100
7.250      0.826  -97.176    2.343   104.75      0.0895   29.285     0.616   -48.447
7.500      0.824  -99.356    2.306   102.84      0.0910   28.167     0.613   -49.689
7.750      0.819  -101.37    2.256   101.01      0.0915   26.850     0.611   -50.450
8.000      0.816  -103.51    2.210    99.422     0.0936   25.811     0.603   -51.700
8.250      0.811  -105.59    2.168    97.874     0.0953   24.422     0.599   -52.672
8.500      0.804  -107.40    2.122    96.200     0.0952   22.700     0.603   -53.200
8.750      0.802  -108.98    2.079    94.429     0.0954   22.214     0.606   -54.999
9.000      0.800  -110.63    2.040    92.922     0.0964   21.578     0.605   -56.256
9.250      0.796  -112.30    2.006    91.287     0.0979   20.912     0.604   -57.275
9.500      0.795  -113.96    1.968    89.644     0.0989   20.011     0.605   -58.367
9.750      0.792  -115.64    1.926    88.103     0.0997   18.699     0.605   -59.533
```

Figure 1 MMICAD Circuit File For Automated Computer-Aided Testing

(d) FREQ Block Syntax

SWEEP <Start> <STOP> <STEP>
ESWEEP <START> <STOP> <N>
FIXED <F1>
STEP <F1> <F2> ... <Fn>

SWEEP is used to create a linear sweep, **ESWEEP** is used to create an exponential sweep, **FIXED** is used to specify the frequency for Parameter mode analysis, and **STEP** is used to specify a list of discrete frequency points.

(e) PARAM Block Syntax

A sweep is defined corresponding to the required bias sweep. The syntax is similar to the **FREQ** block.

(f) OUT Block Syntax

<Network> <Measurement> <Frame> <Control>

<Network> is a the network name defined in the FILES blocks

<Measurement> can be both a tabular or non-tabular measurement.

The format for tabular measurement is one of

SPAR	for S-Parameters in Magnitude-Angle format
YPAR	for Y-Parameters in Magnitude-Angle format
ZPAR	for Z-Parameters in Magnitude-Angle format

The format of non-tabular measurement is

<FORMAT> [<Parameter>]

where **<FORMAT>** is one of

ANG	for angle
DB	for Decibels
DBN	for inverted sign Decibels
IM	for imaginary
INTGR	for integration
MAG	for magnitude
PHA	for phase
POL	for polar charts
RAD	for angle in radians
RE	for real part
SLOPE	for derivative
SMI	for smith charts
VSWR	for voltage standing wave ratio
TD	for group delay

and **<Parameter>** is one of

GMAX	for maximum available gain
GM1	for simultaneous match reflection coefficient on the input
GM2	for simultaneous match reflection coefficient on the output
K	for Rollet's stability factor
Sij	S-Parameters of the n-port
Yij	Y-Parameters of the n-port
Zij	Z-Parameters of the n-port

<Frame> is an arbitrary output frame name. MMICAD allows several measurements to be displayed in the same output frame by using multiple OUT statements. This enables users to store data files with arbitrary formats.

<Control> is optional, and can be **T** to force an output frame to be tabular, or **S** to save an output frame into a data file.

The complete circuit file is shown in Figure 1. In the **FILES** block, S-Parameters are assigned to the network name "**MESFET**". The variables VG, and VD are defined in the **VAR** block. The variables IG and ID are also defined with initial values. When MMICAD acquires data from the KEITHLEYs, it assigns the measured values for the current into IG and ID. The commands for the KEITHLEYs are defined in the **IEEE** block.

When **VARIATIONAL ANALYSIS** is started, MMICAD sources the biases into the KEITHLEYs and measures the currents. Then it prompts the user to ready the ANA measurements by contacting the MESFET with the RF probes. MMICAD, without further involvement by the user, begins to automatically acquire S-Parameters from the WILTRON and displays and saves the data into auto-incrementing filenames begining with "FETSET1.S2P" corresponding to VG=-2.0 and VD=4.0; next file saved would be "FETSET2.S2P" corresponding to VG=-1.9 and VD=4.0, and stops after saving "FETSET23.S2P" corresponding to VG=+0.2 and VD=4.0. The commands defined in the **IEEE** block, including the measured currents are automatically pasted into each data file. As an example, the data file name "FETSET18.S2P" corresponding to VG=-0.3 and VD=4.0 is shown pasted between the **FREEZE ON** (start comments) and **FREEZE OFF** (end comments) blocks.

Suppose now that you would like to analyze the MESFET parameters from the extracted data files at some later point. Using MMICAD's unique **PARAM** sweep and **VARIATIONAL ANALYSIS**, MMICAD provides a versatile function that allows users to read large number of auto-incrementing data files.

This is done in the **FILES** block in MMICAD by replacing the incrementing number in a data file set with a question mark ("?").

The question mark is replaced by the value of the parameter that is swept in the **PARAM block.** For example, figure #2 shows a circuit file that reads FETSET1.S2P, FETSET2.S2P, ... to FETSET23.S2P from \MMICAD\WORKING\ directory, and displays maximum available gain, forward gain, input and output reflections as a function of gate bias (figure #3).

MMICAD 5.0	LINEAR ANALYSIS AND CIRCUIT DESIGN	OPTOTEK LTD	
FILE NAME: APP27B.CKT		AUTHORS: MMICAD Authors	04/30/1992

```
** AUTOMATED COMPUTER-AIDED-TESTING of a MESFET as function of Gate Bias **
   Using VARIATIONAL ANALYSIS, MMICAD automatically reads and analyzes
   S-Parameters from auto-incrementing data files

 FILES
   C:\MMICAD\WORKING\FETSET?.S2P MESFET 502 2P ! "?" is replaced by value of PARAM
 FREQ
   SWEEP   1.0  10  0.25
 PARAM
   SWEEP   1    23  1                          ! Read FETSET1.S2P TO FETSET23.S2P
 OUT
   MESFET DB[GMAX] MAXGAIN                     ! Maximum Available Gain Output
   MESFET DB[S21] GAIN                         ! Forward Gain Output
   MESFET SMI[S11] SMITH-S11                   ! Input Reflection Output
   MESFET SMI[S22] SMITH-S22                   ! Output Reflection Output
 GRID
   RANGE 1  10  1
   MAXGAIN  0  30  3
   RANGE  1  10  1
   GAIN  -20  20  2
 LABEL
 Auto Analysis of data files
```

Figure 2 MMICAD Circuit File for Reading Auto-Incrementing Data Files

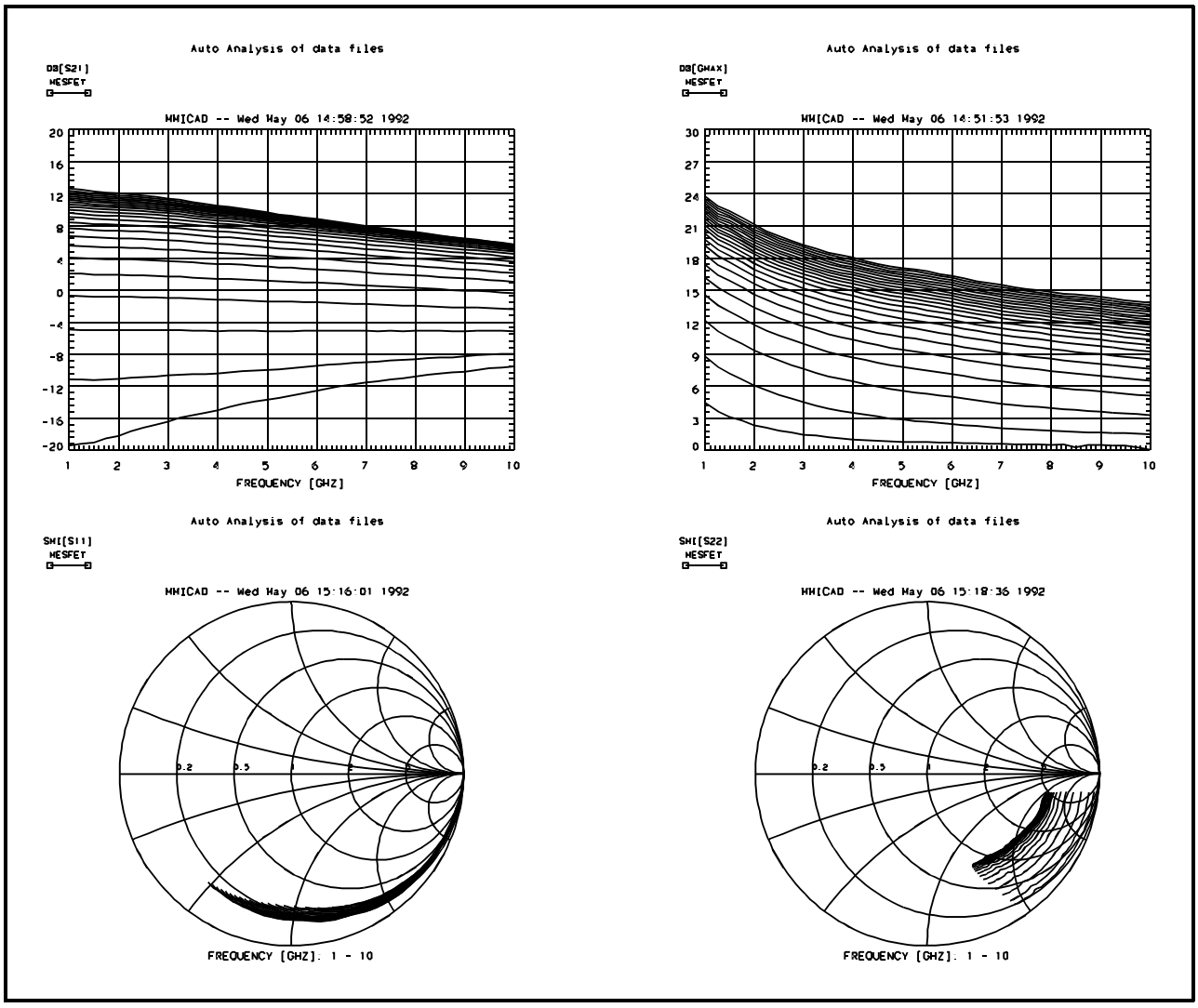


Figure 3 Input Reflection, Output Reflection, Maximum Available Gain and Forward Gain as a Function of Gate Bias