CONTROLLING AN INTEGRATED AUTOMATIC PARAMETER CHARACTERIZATION SYSTEM WITH FORTH

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ABSTRACT:

An integrated automatic parametric characterization system for semiconductors has been developed in GTE COMMUNICATION SYSTEMS. The system consists of an automatic testing and measuring system, a database, and extraction algorithms for device parameter. This paper describes an automated system that fulfills these modeling tasks for existant and future technologies. The architecture of this system, the operation of the software, and a brief description of design methodology based upon FORTH and the tradeoffs between FORTH and BASIC for this application are discussed.

INTRODUCTION:

The modeling of semiconductor device characteristics requires empirical correlation with theory. The complexity of the theory and processing performed manually would be very time consuming and the results prone to error. An automated system has been developed that can be universally applied to measure any desired quantity or parameter of a device [or circuit]. The circuit design engineers have a great deal of interest in the device paremeters for circuit modeling because these parameters influence the performance of circuits very significantly. section I describes the architecture and function of the hardware, section II describes the software implementation and the tradeoffs between FORTH and BASIC for this particular application. Section III discusses the application of this system and contains an example. Future developments are presented in section IV.

SECTION I. The Architecture Of The System

The architecture of this system is shown in figure 1. The heart of the system is the matrix. This unit allows any stimuli (maximum frequency capability 200MHZ) to be applied to any particular output port on device structures or circuits, and can monitor any desired response. This matrix approach is extremely versatile in that it allows an almost unlimited number of test configurations to be applied, limited only by the test instrument configuration and controller. The user interface for the system is a VAX 11/780 host computer which provides a menu-driven interface, a database for storage of measured data, and many post-processing aids. The HP9836 waits for a command from the VAX, interprets and executes the command, activates or deactivates a particular piece of equipment, sets up the appropriate matrix connections to the test circuit for measurement, and sends the message/data back to the VAX.

The HP9836 talks and listens to instruments via an HPIB bus so that any instrument with HPIB capability bus can be connected into the system easily. The test instruments consist of voltage and current supplies, voltage, current and capacitance meters for the measurements of I-V and C-V characteristics, signal generators and frequency meters for the measurements of AC characteristics, an automatic prober and a plotter.

SECTION II. The Software Implementation

It is the first time that FORTH has been used for this application according to my knowledge. Most of the parameter extraction systems available are implemented in BASIC. There has been a big argument for the choice of FORTH rather than BASIC. The disadvantages of FORTH in this application are the incompatibilities with the rest of the parameter extraction system. Since the examples of instrument drivers in the manual are written in BASIC, the drivers need to be rewritten if FORTH is chosen. If the end user, such as a device engineer, wants to have some insight to the system, he would like to have the software written in BASIC due to its widespread use. The advantages of FORTH over BASIC in this application are:

- Compact code: Usually the length of FORTH code is shorter than any other language due to the special structure of FORTH.

- More readable and better modularized: Based on the structure that FORTH uses issuing vocabularies to define a sentence, it is much more readable than traditional programs.

- Very easy to debug: The FORTH system can be activated at any point where a word is defined, which is very helpful to debug and isolate problems during development.

Based on the advantages listed above, the system is very easy to maintain, and FORTH was finally chosen for this project.

The architecture of the software is shown in figure 2. Users can activate the system at a VAX (or HP9836) site. The HP9836 is transparent to the user. The reasons for this approach are the following:

1. Users, such as device engineers, usually want to do postprocessing on the measured data, such as SPICE model parameter calculation, AC analysis, small signal analysis, etc. Users do not want to learn the new language (FORTH) and the new system (HP9836). Some post-processing tasks are very time consuming and must be implemented on a host computer, such as a mini or main frame computer.

2. The major software programs, such as SPICE (circuit simulator), GEMINI, MINIMOS (device simulator), or SUPREM (process simulator), with which the system must interface, run on a Vax

3. This approach allows users to activate the system remotely. This feature is very important for GTE, since GTE has many divisions located in different locations. Because the computers of each division are connected by TELENET and DECNET, users may activate the system from any location.

In designing the software, the various operations which would be used were investigated. FORTH words were designed for the more frequently used operations, such as string handlers like write a string, reserve spaces for a string, clear a string, etc. Global variables were carefully selected to optimize performance, and the stack was used to transfer parameters between words. Variables were defined to be as meaningful as possible.

This resulted in easy program development and debugging procedures.

SECTION III. Applications And Examples

This system has been used in many different applications. One of the applications will be illustrated in this section, which will provide some insight into the capabilities of the system.

The most common use of this system is in the characterization of MOS devices. This requires current as a function of applied voltages from which the device parameters can be obtained through extraction algorithms. One of the basic relations is the device I-V characteristic (drain current vs. drain voltage). The following example is of a channel device.

First, the circuit to be measured is set up. One voltage source and current meter is tied to the drain of the device and ground, the other voltage source is tied to the gate of the device and ground, and the subtrate and source are tied to ground. The circuit and command file for the measurement are:

```
CLR MTX           / clear the matrix connection /
RESET             / clear HPIB bus universally /
GND P19 HOOK      / connect the ground to P19 which is used as chasis /
                  / ground /
IMOH P17 HOOK     / connect the voltage source and current meter to /
                  / the drain which is pin 17 /
VF2H P10 HOOK     / connect the voltage source to the gate which is /
                  / pin 10 /
GND P9 HOOK       / connect the subtrate and source which is pin 9 to /
                  / ground /
MAP-MTX           / make the matrix do the connections listed above /
2.0E0 VF2!        / set the vgs to 2V /
LISTEN            / VAX listens to HP9836 to get the measured data /
0.0E0.8.0E0.0.1E0 VFIM VAX / sweep the voltage source from 0V to 8V /
                  / with the 0 1V step size and monitor the current /
3.0E0 VF2!
LISTEN
0.0E0.8.0E0.0.1E0 VFIM VAX
4.0E0 VF2!
LISTEN
0.0E0.8.0E0.0.1E0 VFIM VAX
5.0E0 VF2!
LISTEN
0.0E0.8.0E0.0.1E0 VFIM VAX
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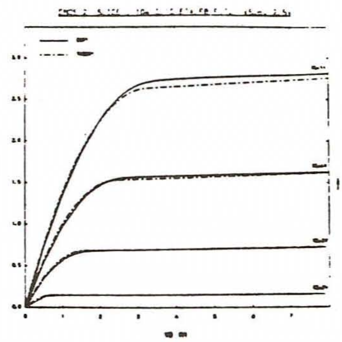

The dashed line is the theoretical result obtained from simulation and the solid line is the experimental data obtained from this system.

The above example is just a part of the system. There is a menu driven interface, postprocessing and database implemented in C, and an automatic routine for the extraction of SPICE level 2 model parameters implemented in VMS command language on the VAX. If the user wants to develop a new technique to extract the device model parameters, the measurement sequence needs to be defined and implemented in VAX command language which is used in the above example to do the actual measurements. Then this VAX command language file can be integrated with the rest of the system.

SECTION IV. Future Developments:

The continuing development in this project is related to post processing, such as interfacing with different device simulators and process simulators.

The device model parameters of a new or modified device or the effects of fluctuation of a process on model parameters also interest many people. Information on this can be obtained theoretically through device and process simulations over a relatively short period. At a later date when the new or modified devices are processed or if many batches have been processed to investigate statistical variation, the parameter extraction system will be used to correlate experimental data with theoretical data. This comparison provides very important information on the validity and accuracy of circuit, device and process models. These sections will be implemented to create a fully automated system.

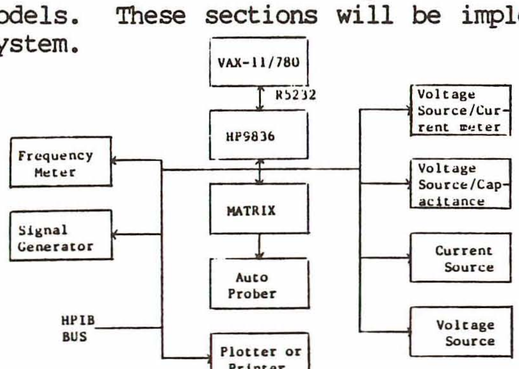

Fig. 1

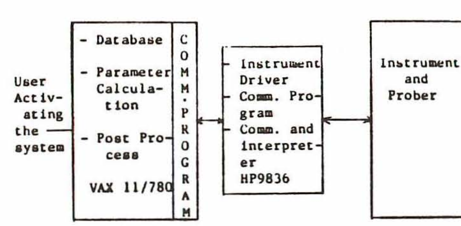

Fig. 2