Journal of American Science

Websites:
http://www.jofamericanscience.org
http://www.sciencepub.net

Emails:
editor@sciencepub.net
sciencepub@gmail.com

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

MODELING AND SIMULATION OF ADVANCED FIELD EFFECT TRANSISTOR STRUCTURES

Suneel Kumar

Assistant Professor (EL), Government College, Hodal, Haryana (India)
suneel25.kumar@gmail.com

ABSTRACT: An advanced field-effect transistor is a semiconductor device that uses the electric field effect of the control input circuit to control the output circuit current and is named after it. Because it only depends on the majority carrier in the semiconductor to conduct electricity, it is also called the unipolar transistor. There are two main types: junction FET (JFET) and metal-oxidesemiconductor FET (MOSFET). A model may incorporate logical, mathematical and structural aspects of the system or process. A discrete-event model, the type discussed in this paper and the type represented by the great majority of papers at the Winter Simulation Conference, is one based on the concepts of state, events, activities and processes. Time is a critical component. A discrete-event model is one whose state changes only at discrete times called event times. When an event occurs, it may trigger new events, activities and processes. Simulation is a powerful tool for the analysis of new system designs, retrofits to existing systems and proposed changes to operating rules. Conducting a valid simulation is both an art and a science. This paper provides an introduction to simulation and modeling and the main concepts underlying simulation. It discusses a number of key issues regarding a simulation team, how to conduct a simulation study, the skills required and the steps involved. It also provides project management guidelines and outlines pitfalls to avoid.

[Kumar, S. **MODELING AND SIMULATION OF ADVANCED FIELD EFFECT TRANSISTOR STRUCTURES.** *J Am Sci* 2022;18(12):19-23]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 02.doi:10.7537/marsjas181222.02.

Keywords: MODELING; SIMULATION; ADVANCED; FIELD; EFFECT; TRANSISTOR; STRUCTURES

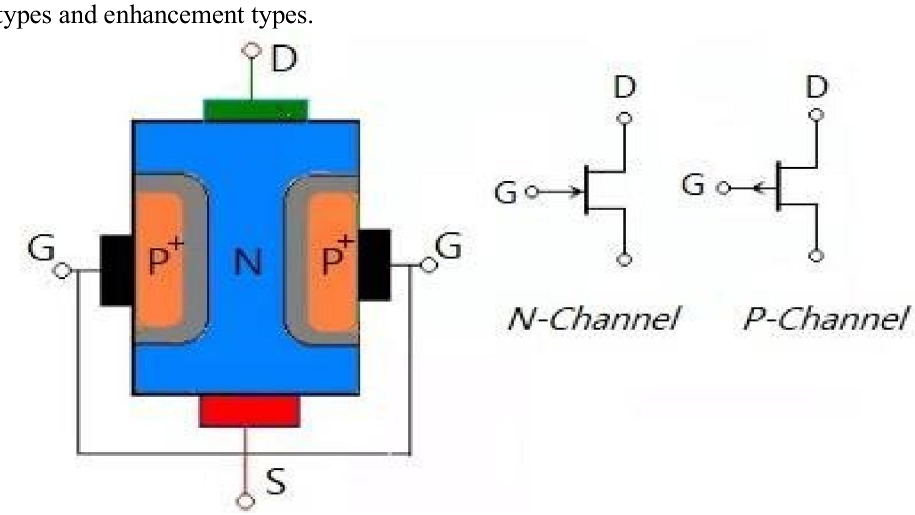
Introduction:

Structure and Working Principle

Field-effect transistors are divided into two categories: **junction field-effect transistors (JFET)** and etal**oxidese miconductor field effect transistors (MOSFET)**. According to the channel material type and insulated gate type, there are N channel and P channel transistors; According to the conduction mode, there are depletion type and enhancement type. JFETs are all depletion types, and MOSFETs have both depletion types and enhancement types.

Structure

The structure of the N-channel junction field effect transistor is shown in the following figure. It is a structure where a PN junction is fabricated on each side of the Ntype semiconductor silicon wafer, forming a structure in which two PN junctions sandwich an N-type channel. The two P regions are the gates, one end of the N-type silicon is the drain, and the other end is the source.



Working Principle
Take the N-channel as an example to illustrate its working principle. When VGS=0, when a certain voltage is applied between the drain and the source, a majority carrier will drift between the drain and the source, generating a drain current. When VGS<0, the PN junction is reverse-biased, forming a depletion layer. The channel between the drain and the source will narrow, and the ID will decrease. If VGS continues to decrease, the channel will continue to narrow, and the ID will continue to decrease until it reaches 0. When the ID is 0, the corresponding VGS is called the pinch-off voltage VGS (off).

Characteristic Curve of Junction FieldEffect Transistors
There are two characteristic curves of the junction field-effect transistor,One is the output characteristic curve (ID=f(VDS) | VGS=constant), the second is the transfer characteristic curve (ID=f(VGS)|VDS=constant).

The characteristic curve of the N-channel junction field effect transistor is shown in the figure below.

***(A)** Drain Output Characteristic Curve*

***(B)** Transfer Characteristic Curve*

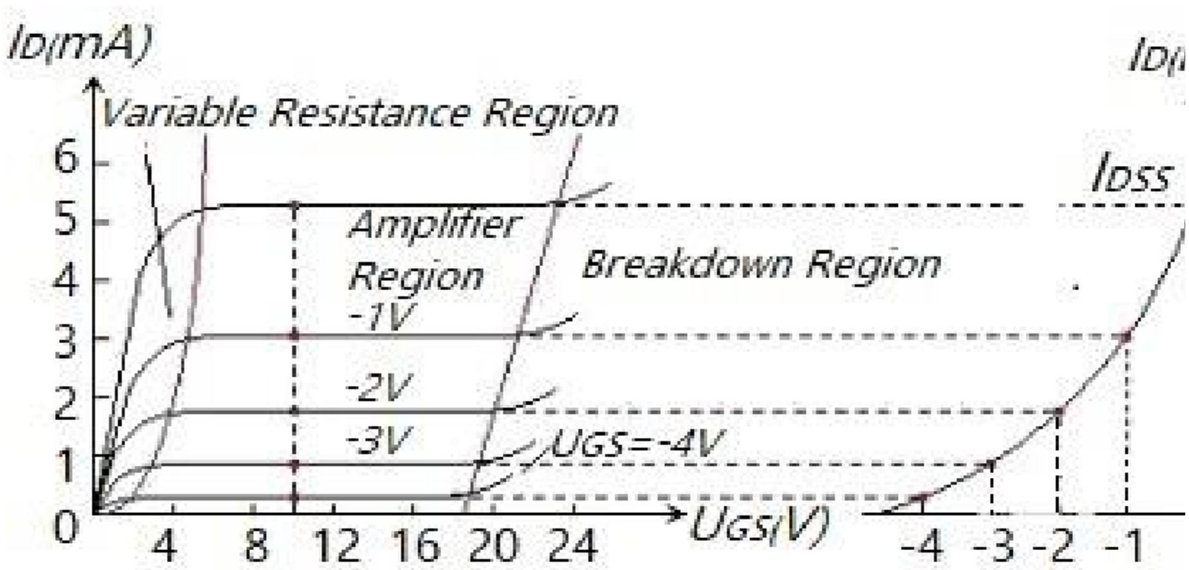


Figure 2. The Characteristic Curve of the N-channel Junction Field Effect Transistor

Advanced Field Effect Transistor Parameters
There are many parameters of field-effect transistors, including DC parameters, AC parameters, and limit parameters, but in general, we only need to pay attention to the following parameters.
(1) Pinch off Voltage (UP) This refers to the voltage UGS applied to the gate when the drain current /D (ie, channel current) is zero or less than a small current value (for example, 1µA. 10µA) under the specified drain voltage UDS. It is an important parameter of junction or depletion type MOS field-effect transistors.**(2) Turn-on Voltage (UT)**This is the gate voltage UGS when the conductive channel (between the drain and the source) is just turned on when the drain voltage UDS is at a certain value. It is an important parameter of the enhancement field-effect transistor. When the gate voltage UGS is less than the absolute value of the turn-on voltage, the field-effect transistor cannot be turned on.**(3) Saturation Leakage Current (DSS)**It refers to the saturation leakage current of the drain current D caused by a certain drain voltage UDS (greater than the pinch-off voltage) when the gate and source are shorted (UGS=0). It reflects the conduction capability of the original channel at zero gate voltage, which is an important parameter of depletion field-effect transistors.
(4) Low-frequency Transconductance (gm)
When the drain voltage UDS is at a specified value, the ratio of the drain current change to the gate voltage change ΔUGS that causes this change is called transconductance, that is:

$$gm = \frac{\Delta D}{\Delta UGS}$$

The common unit of gm is mS (millisiemens). gm is a parameter that measures the strength of the gate voltage of the field-effect transistor on the control of the drain current, as well as the amplification effect. It is similar to the AC amplification factor of the transistor β and is related to the working area of the transistor. The greater the drain current /D, the greater the gm.

(5) Drain Source Breakdown Voltage (BUDS)

This refers to the maximum drain voltage that the field-effect transistor can withstand when the gate voltage UGS is constant. It is equivalent to the collector-emitter breakdown voltage V(BR)ceo (ieBUceo) of a common crystal transistor. This is a limit parameter, and the working voltage applied to the field-effect transistor must be less than BUDS.

(6) Maximum Drain-source Current (DSM)

This refers to the maximum current allowed between the drain and the source when the field-effect transistor is working normally. It is equivalent to the operating current of the common crystal transistor. This limit parameter should not be exceeded.

(7) Maximum Power Dissipation (PDSM) This refers to the maximum drain power dissipation allowed when the performance of the field-effect transistor does not deteriorate, which is equivalent to the Pcm of an ordinary transistor. When in use, the actual power consumption of the fieldeffect transistor (PD=UDS×/D) should be less than this limit parameter, and leave a certain margin.

Buried Triple-Gate Structures for Advanced Field-Effect Transistor Devices

One key element in the investigation of novel channel materials and device principles is the realization of an appropriate source-drain doping profile. The paper at hand describes the manufacturing of a buried triple-gate (BTG) structure, where three separately addressable gates are implemented to control the charge carrier density within source, drain, and the channel of a fieldeffect transistor. The BTG structure is optimized for the investigation of graphene, and a 30 nm graphene nanoribbon is fabricated on top of the structure. Electrical measurements at 25 K indicate the successful realization of p-n junctions and demonstrate band-to-band tunneling at the source-channel and channel-drain interfaces.

Simulation Worldviews

Simulation modeling software usually takes one of three worldviews: event scheduling, process interaction, or activity scanning. As their names suggest, each puts its main focus on the events, the processes, or the activities in a simulation, respectively. When following an event scheduling perspective, a model developer must define the model logic and system state changes that occur whenever any event occurs.

A process is a sequence of events, activities and other time delays associated with one entity as it flows through a system. For example, a customer process at a bank consists of an arrival event (to the lobby, perhaps), joining and waiting in a queue (a delay), a service time by a teller, and finally a service completion event. In terms of concepts discussed earlier, the service time is an activity and the teller is a resource. Simulation software based on the process interaction perspective, or worldview, provide a way for a user to define a process for each entity in the system.

Activity scanning provides a way to define model logic by focusing on activities from the point of view of a resource, defining resource state changes depending on various events. For example, in the bank, the teller serves one customer until completion, then looks at the queue. If the queue is not empty, the teller "takes" the first entity out of the queue, changes its own state to "busy" and begins a new service activity. If the queue is empty, the teller changes its own state to idle.

The Simulation Analyst: Skills and Software

For a simulation analyst, simulation is both an art and a science. As with any art, one learns by training and education but more importantly by practice and mentoring. Good communication skills are a necessity; a willingness not to assume anything, not to be afraid to ask "stupid" or "obvious" questions, and a willingness to ask the same question of many team members is a key to understanding and making accurate assumptions. For the science portion, programming, modeling, and a working knowledge of probability and statistics are important skills to attain. Knowledge of a simulation package, while necessary, by itself is not sufficient to be a good simulation analyst.

Models should be developed in a suitable, commercially available and supported simulation package. There are many simulation packages, some more or less general purpose, and some that specialize in either one or a few application domains (such as manufacturing, material handling, call centers, medical, transportation, logistics or other limited area of applicability). Packages offer differing levels of detail, ease of use, and skill required for effective use, as well as differing levels of user customization capability. Some have minimal or no programming, emphasizing ease of use and quickness of model development for small to medium-size models with minimal complexity. Other packages offer total customization but usually at the cost of programming skill, time and effort as well as gaining a knowledge of the selected package. Large complex models with unique rules and algorithms cannot be developed in most (or possibly any) “no-programming” packages. On the other hand, many simpler simulation models can be developed most efficiently and quickly in the simpler “point & click” environments based on flow charting.

The actual choice of software used is beyond the scope of this introduction, but is often heavily influenced by what the simulation analyst has used in the past. This is a valid consideration, as learning a new simulation package can be time-consuming, and becoming an expert in it takes a number of projects and an openness for self-education.

A new simulation analyst with a programming background may think, on seeing the price range of simulation packages, that a model can be developed in a general purpose non-simulation programming language, such as C or C++ or Visual Basic, with less expense and in about the same time. This judgment is based on inexperience; in the author's experience, using a general purpose language, even with a library of simulation routines, generally takes from 4 to 10 times the amount of analyst time for model development as using a good simulation package; maintaining or extending such a model usually requires the original developer, and can be a challenge (to put it nicely).

To be successful with most simulation packages, a new analyst needs training from an expert and ongoing mentoring for a period of time. Self-education is sometimes possible, but usually results in a “spotty” knowledge with learning gaps if used as a total solution.

Problem Formulation and Setting of Objectives

All modeling activities should be focused on the objective. Often, the actual problem may be unknown or little under- stood, and problem formulation may initially be stated in terms of observed symptoms (for example, product throughput less than desired or expected). During the study, as the nature of the problem becomes clearer, problem formulation may be restated and clarified with the project team.

During this phase, the simulation team should develop a list of specific questions that the model should address, and develop a list of measures of performance that will be used to evaluate or compare the alternatives being modeled. Often, the customer has a goal in mind; for example, that the new system under a certain level of resources and manning will achieve an expected throughput. This means that if the study finds that the proposed system design or set of operating rules does not achieve the expected throughput, then the model is expected to provide information and insight into the causes, so that the simulation analyst and team can develop intelligent alternatives that have a better chance of achieving desired goals.

At this phase, the simulation analyst (or project leader) needs to ask questions of all participants and develop a set of working assumptions that will form the basis for model development. Three important overall considerations are:

Model boundary and scope, Level of detail, Project scope.

The model boundary or scope determines what is in the model, and what is out. The model level of detail specifies how in-depth one component or entity is modeled; it is determined by the questions being asked and data availability. Think of model boundary as “width” and level of detail as “depth”. Overall project scope deals with the breadth of the questions that the model will be used to address; that is, it deals more broadly with how the model will be used during the experimentation and analysis phase. As more and more questions can be asked of a given model (especially a parameterized one), the team needs a common understanding of project scope to avoid scope creep and a project with no end.

Overall Project Plan

With the information developed during problem formulation, the simulation analyst should develop time estimates and project timelines for model development, verification and validation, and experimentation and analysis - all the steps in a simulation.

With these time (and cost) estimates in hand, management can decide whether to proceed with the simulation study, or possibly to expand or limit its scope.

WHAT ARE SOME PITFALL TO GUARD AGAINST IN SIMULATION?

Simulation can be a time consuming and complex exercise, from modeling through output analysis that necessitates the involvement of resident experts and decision maker in the entire process. Following is a checklist of pitfalls to guard against.

- Unclear Objective
- Using simulation when an analytic solution is appropriate.
- Invalid model
- Simulation model too complex or too simple.
- Erroneous assumptions.
- Using the wrong input probability distribution.
- Using the wrong performance measure.
- Bugs in the simulation program.
- Using standard statistical formulae that assume independence in simulation output analysis.

REFERENCES

[1]. Banks, J., J. S. Carson, II, and B. L. Nelson. 1996. Discrete-Event System Simulation, Second Edition, Prentice Hall.

[2]. Bratley, P., B. L. Fox, and L. E. S&rage. 1987.A Guide to Simulation, SecondEdition, Springer-Verlag.

[3]. Fishwick, P. A. 1995. Simulation Model Design and Execution: Building Digital Worlds, Prentice-Hall.

[4]. Freund, J. E. 1992. Mathematical Statistics, Fifth Edition, Prentice-Hall.

[5]. Hogg, R. V., and A. T. Craig. 1995. Introduction to Mathematical Statistics, Fifth Edition, Prentice-Hall. Jaralmuiation Practitioners, Marcel Dekker, New York.

[6]. Law, A. M., and W. D. Kelton. 1991. Simulation Modeling and Analysis, Second Edition, McGraw-Hill.

[7]. Law, A. M., and M. G. McComas. 1991. Secrets of C.,Ff.aenfi.l c;m,,1.&nn ctlu-l;,an 1991 Winter Simulation Conference, ed. J.

[8]. Maria, A., and L. Zhang. 1997.Probability Distributions, Version 1.0, July 1997, Monograph,

[9]. Department of Systems Science and Industrial Engineering, SUNY at inghamton, Binghamton, NY 13902.

12/5/2022