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STUDY OF PARAMETER VARIATION UNDER THE INFLUENCE OF TEMPERATURE IN DIODES USING VIRTUAL INSTRUMENTATION

BY

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Abstract. The paper describes a practical application in the field of electronics, using the general concept of virtual instrumentation, particularly devoted to virtual laboratories *e*-learning techniques. The application uses for implementation the LabVIEW graphical programming language in order to make simulation of this work, where the student will have to observe and experiment the effect of potential barrier in diodes and the influence of temperature on their operation.

Key words: *e*-learning; virtual laboratory; logical pattern.

1. Introduction

The implementation and use of modern technologies in education and research requires the mobilization and support of various initiatives, programs and projects of public institutions, professional organizations or individually of experts in the field of *e*-learning (James, 1998; Bonaiuti, 2006), researchers, teachers, university professors, inspectors, advisers, educators, psychologists, high school students and university students.

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Nowadays, the computer is, indisputably, a good way of training the teaching staff. We can say that it is an instructive, revolutionary way, with an impact on the educational process as there has never been from the moment of appearance of textbooks.

In terms of the impact on students, over 80% of teachers believe that students are more attracted to classes due to animation and multimedia content and examples from real life and virtual simulations capture their attention and help them more easily to retain information about the school subject. The computer has become essential in modern education (Pelgrum, 2001), being used by teachers in the teaching and learning process. Being a modern way of education, the use of computer systems has gained ground due to very attractive virtues for students, to their accessibility and to their way of facilitating the presentation of information.

Computer use in education has the great advantage of facilitating the transition from passive accumulation of information by students, to learning by discovery; they learn to learn, developing this way their skills and cognitive strategies that they will use and adapt in various other situations. This brings great flexibility in learning and stimulation of students to get involved in the educational process and become partners of the teacher in the classroom. The simulations used in the virtual classroom are often spectacular for students.

The development simulation techniques (Ferrero, 1998; Benetazzo, 2000) and computer aided design is the result of the increasing complexity of electronic systems, which is an important step in education.

Through simulation, using the computer both analogue and digital components and electronic and electrical circuits can be analysed and tested and, without having to actually experiment them. Thus, complex, flexible, accurate, reliable and cheap analyses can be carried out, taking into account the effects of changes in parameters of components, the effects of component failures, the behaviour of expensive devices and/or difficult to purchase and the behaviour of devices and circuits under certain physical conditions very difficult or unlikely to practical analyse.

The simulation allows the user quick study and understanding of the functioning of circuits (Ferrero, 1998), in a manner that is situated between theory and practice and ensures, for the practitioner, finding much faster the optimal solution. In this way one can make determinations on the static operating point, on the small signal in response in sinusoidal phase, on the sensitivity to the variation of circuit parameters, on the statistical variation of parameters of electronic components and on their effects on the response of simulated circuits, on the response in the transient phase, on the behaviour of electronic components and circuits in the worst cases, on the effect of temperature, noise, distortions, and on the behaviour in the frequency (Fourier analysis).

The application presented below concerning the type of simulated virtual laboratory, is dedicated to the study of the direct and reverse polarization effect in germanium and silicon diodes, and to the observation of the potential barrier effect of the diode, respectively to the highlighting of the advantages of using silicon diodes compared to the germanium ones when the temperature is an important factor.

This paper is designed to be accessed remotely *via* a Web browser, containing all the elements of a real application, starting from theoretical considerations and ending with the experimental data processing. The application is designed in LabVIEW development environment in order to benefit both from the attractive graphical presentation of information on friendly front panels and from the extremely powerful libraries of functions that facilitate the software development of the application. The work is part of an *e*-learning system implemented in the school, through which other virtual laboratory type experiments related to electric can be accessed.

2. The Structure of the Laboratory Work

Modern information technology enables the study in a simulated environment of electronic components – in this case the diode – where all the phenomena related to this component are shaped by mathematical relations implemented in the LabVIEW programming environment.

2.1. Architecture of the Virtual Laboratory

The laboratory presented in Fig 1 is used to carry out both simulated works and real experiments , of variable complexity, on analogue and digital circuits (Kocijancic, 2002) and includes both software and hardware component, related to the experiments taken into consideration.

The design of this laboratory is structured on three levels as can be seen in the Fig 1 namely

a) The first level consists of real instruments, the experiment level contains all the necessary hardware elements, such as: the studied device (engine, electronic circuit, diode, transducer, etc.), signal generators, power units, the relays and switches, measuring instruments, oscilloscopes, signal analysers, etc.

b) The second level, intermediate, allows the recording of the resources and the measuring of the execution cycles. At this level, multiple user management can be organized, and this supposes their programming.

c) The third level is composed of two separate graphical interfaces: the execution interface and the composition interface.

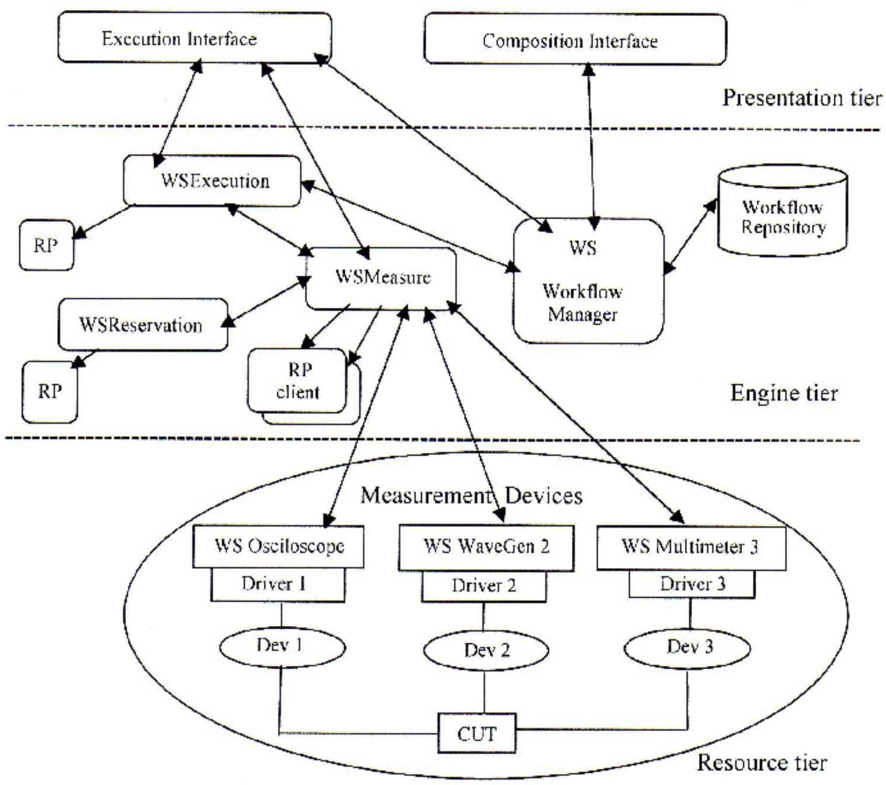

Fig. 1 – The architecture of a modern virtual laboratory.

The execution interface allows the user to perform a measurement by sending the appropriate settings of the devices and receiving the results. The composition interface can be used by the laboratory manager to create a new measurement cycle. Both interfaces are Web applications and can be accessed using a common browser. The architecture is characterized by high modularity and can be distributed across multiple servers. In particular, it is possible to reconstruct the WSMeasure component to manage different sets of measuring devices. This architecture is characterized by

a) Service-oriented devices. Each device makes its characteristics known through standard interfaces.

b) Activating the workflow. The devices are controlled sequentially, according to a predefined model called *workflow*. Each flow defines a specific measurement, taking into account the devices involved and the parameter settings.

c) Managing multiple users. Each user controls the device through the workflow and the system is able to manage the simultaneous execution of multiple flows.

d) Managing the sharing of devices. Each device may be included in different flows; the requests for accessing some specific devices are serialized to avoid the conditions of competition.

The work is implemented on the local server, where the simulator runs. The work page runs also on the server.

On the local server are implemented both the database where the teacher receives the processed data for the work undertaken and the evaluation test. The teacher will write each part of the work according to the difficulty level; the final grade is recorded in the user database running on the Web server. The Web work page runs also on the server.

One can find other resources of the *e*-learning platform on the server too. The Web server presents three important functions namely

a) user management;

b) laboratory timetable management;

c) tutor communication management.

The Web page of the work contains the following elements:

1. Theoretical considerations.
2. Arrangement and requirements.
3. Practical application.
4. Final report.
5. Knowledge testing.

The *theoretical considerations* include references to the study of the functioning of diodes. This file of hypertext type also contains reference to reference resources on the Internet or in the application database and remains open throughout the work.

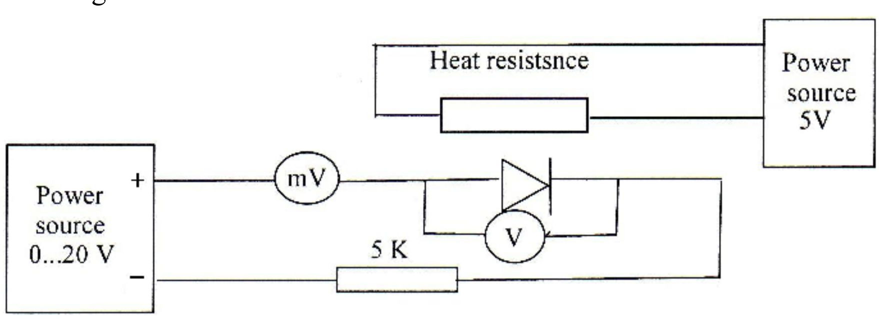

Fig. 2 – Experimental arrangement.

The second section contains both the *arrangement* (Fig. 2), the scheme that will be used in the application implemented in LabVIEW and the *requirements* of this work. Their file is hypertext and contains references to the application database and possibly to other reference resources needed to meet the requirements.

From an analytical point of view, the functioning of the semiconductor diode is described by the functioning equation of the semiconductor diode . This provides the mathematical relation between the diode current and the voltage at its terminals and is represented by the following relationship:

$$I_D = I_S\left(e^{qV_d/NkT} - 1\right). \tag{1}$$

Practical application is the essence of virtual laboratory work, in which the user accesses an application of applet type in LabVIEW. The front panel and the block diagram of the practical application developed as virtual instruments in LabVIEW are presented in Fig. 3.

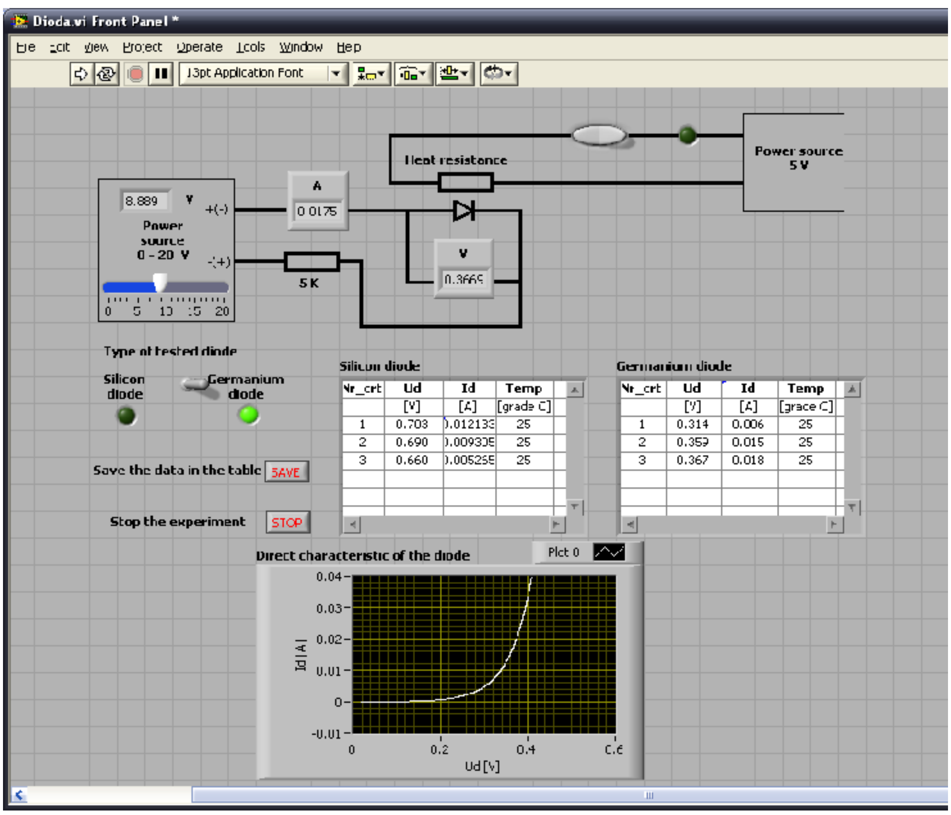

Fig. 3– The front panel of the work “Study on diode functioning”.

The front panel of the virtual tool represented in Fig. 3 contains the arrangement for each of the two cases namely, the study of a silicon diode and the study of a germanium diode, a series of controls, a Slide control used for supply voltage, a Boolean control used for switching on in turns the two diodes and a series of indicators, all of these used to provide data to the user and data that will fill the table in the application. One can also see on the panel a SAVE button that gives the user the possibility to enter the data into the table.

The functions implemented by the main instrument are made in two sequences, namely a first stage is done reading the user input and the GPIB (General Purpose Interface Bus) control of the function generator and in the second, represented graphically in Fig. 4, the acquisition of experimental data, their digital processing and reporting the results take place.

The logical pattern of the work, presented in graphical form in Fig. 4, is made with blocks of computing; the execution of this algorithm is given by the direction of the arrow. To each operation or step a geometric symbol is attached and inside of it the operation to be carried out is registered. The sequence of operations is symbolized by arrows.

As shown in the figure above, the logical pattern begins and ends with a terminal symbol START and, respectively, STOP symbols, that mark the beginning, the end or a point of returning in the logical pattern.

In order to show the entry data in the problem by initializing the data encoding variables with corresponding values or the variables that allow the result display, there were used, as shown in the Fig. 4, a initializing block and a reading block.

Since the temperature influence study was performed for the two types of diodes, in order to introduce in the pattern one of the two types, there was used a logical decision block, the continued processig flow being done on the branch where the condition was met, in our case according to the direct voltage value, one of the two types of diodes presented in the paper will be studied.

Basically, for both types of diodes the same requirements will be carried out.

In order to browse the pattern, there will be used a counter variable, *i*, which is initialized at 1 and it increases by 1 until it reaches the set value, in the above application being 2,000. This is possible by use of the second logical decision block, the branch on which the flow continues being decided according to the value of the variable, namely if it is below 2,000, the flow will continue with the given block for drawing graphs imposed by the application requirements and with a calculus block to determine the tension and voltage going through the diode; if the variable value is over 2,000, the flow will continue with a calculus block and an initialization block of the variable by 1, followed by a return of the flow before the logical decision block in order to start again.

The logical diagram for the given application contains also a printing unit for the experimental data in a table and two separating START blocks that define the end of the algorithm and, respectively, the return to the beginning of the algorithm.

The final report is a Word file in which the student fills a series of tables with the available data and interprets the results of the work. The report obligatorily contains the conclusions on measurement precision and the influence factors. The report is downloaded from the Web page, filled in and then sent to the tutor by e-mail.

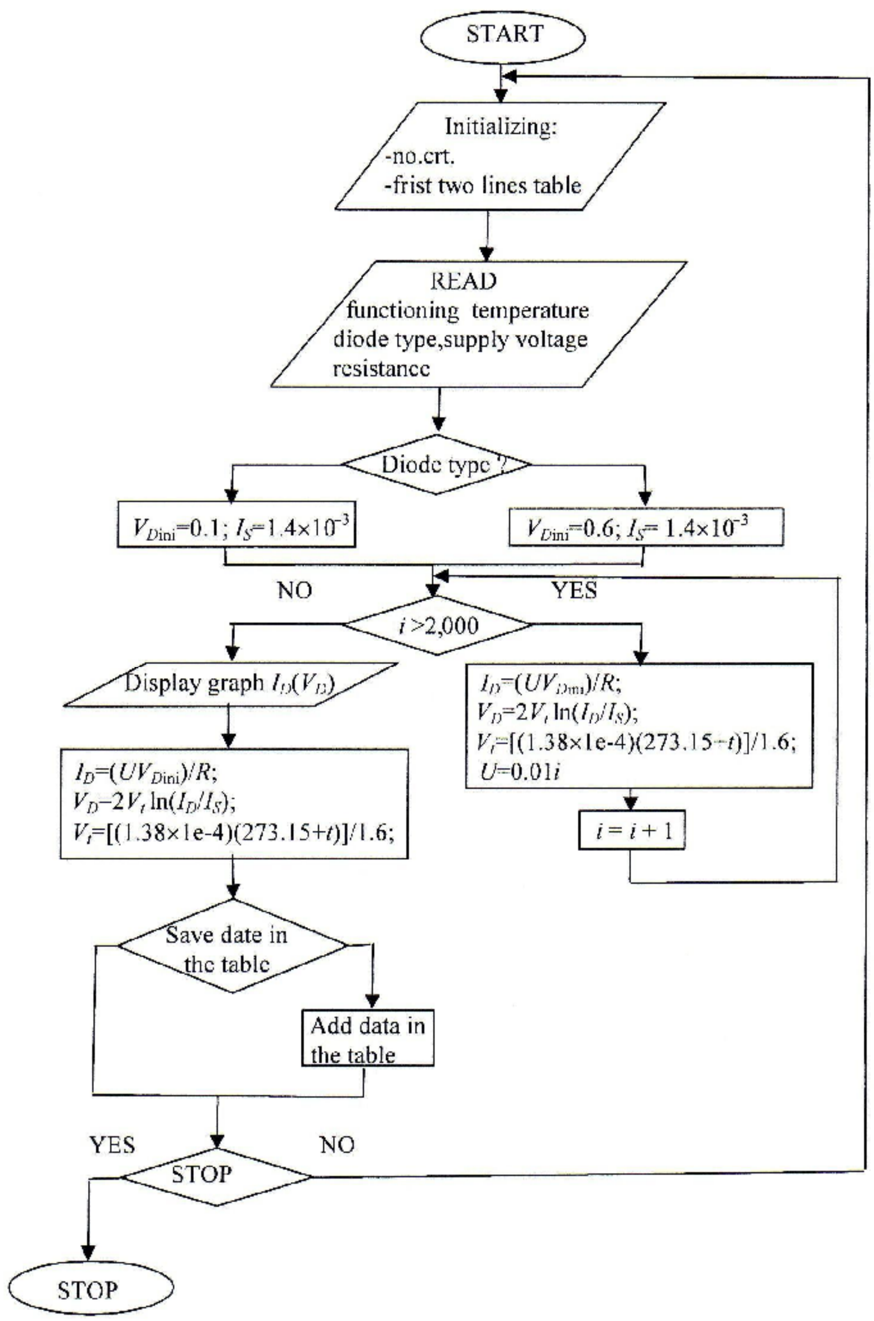

Fig. 4– The logical pattern of the work.

The final test is a series of questions both from the theoretical part and the experiment. It is a multiple choice test with one correct answer. The result is immediately supplied by the management program of the user tests, which is automatically transmitted to the tutor, who takes into account when assessing the final grade of the work.

3. Results

Analysing the expression (1) it can be seen that there is a variation of the brownouts at diode terminals for different values of current through the diode, variation which is very little indeed, this is also why it is considered that the diode terminals, the brownouts, remain constant at around 0.7 V (silicon).

In the expression (1) it can also be seen that the functioning of the diode depends on the working temperature. The term q/KT describes the voltage in the junction P-N due to the temperature action, and is called *thermal voltage* or V_t. At room temperature this voltage is about 26 mV. Also from the relationship (1) it is observed that the diode is a nonlinear circuit element and therefore the circuit that contains it becomes a nonlinear circuit.

It is important to mention that the rise of the temperature has a double effect on the diodes, namely

a) Firstly, the reverse current increases, it doubles with every 10ºC temperature increase; in the diagrams in Fig. 5 we can see the direct current and voltage variation with the temperature for the silicon diode, but also the variation of the reverse current (I_S).

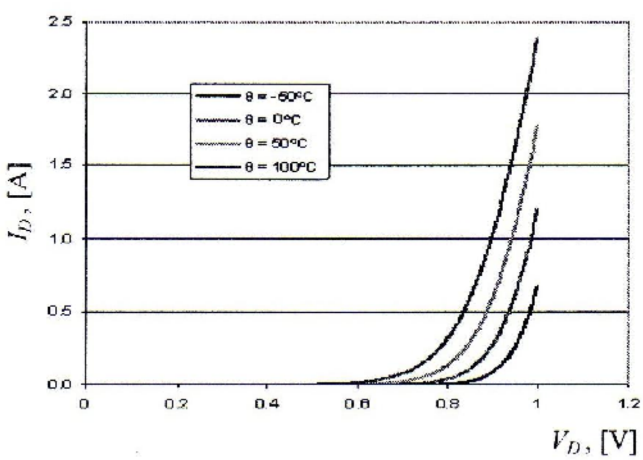

Fig. 5 – Diode characteristics for different temperatures.

As seen from the above characteristics, silicon diode conduction is nonlinear as the current increases exponentially with the direct voltage applied to the diode according to the relationship (1).

b) The second effect of increasing temperature is the voltage decrease on the diode in conduction; the decrease is about 0.002 V/ºC that is why it is sometimes used to measure temperature, being used as temperature sensor; temperature dependence of the direct voltage in the silicon diodes for various values of diode current: I = 1 μA, I = 1 mA, I = 10 mA, is shown in Fig. 6.

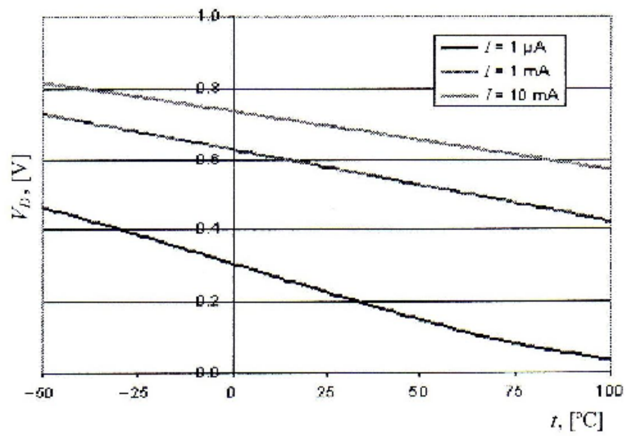

Fig. 6 – Dependences of voltage *vs*. temperature for different currents.

It is also important to mention that the conduction is unidirectional and that is why the diode is used in the alternative voltage recovery circuits in DC.

4. Conclusions

In the present work, a simulated virtual laboratory application designed for technical high school students (electrical profile) to study the diode behaviour in different environments, is conceived in the LabVIEW development environment, having the possibility to be also remotely accessed by a Web browser. This work contains all the elements of a real application, starting with the theoretical considerations and ending with the experimental data processing. This work, presented on a Web page as an applet, gives the user the opportunity to use easily accessible modern information technology.

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STUDIUL VARIAȚIEI PARAMETRILOR SUB INFLUENȚA TEMPERATURII LA DIODE

(Rezumat)

Se prezintă, după conceptul de laborator virtual, un model de aplicație a unei lucrări de laborator din domeniul electric. S-a utilizat mediul de programare LabVIEW, utilizatorii având posibilitatea de a acumula experiențe interactive, bazate pe Web, care urmăresc creşterea nivelului de înțelegere în ceea ce priveşte principiile generale implicate în experimentele simulate.