



HOW TO INCREASE STUDENTS' ACTIVITY WHEN PERFORMING SIMULATIONS OF ELECTRONIC SYSTEMS

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Abstract

When creating educational simulation models, and in classes where computer simulation experiments are used, what frequently happens is that some students meet the targets and achieve the intended educational objectives earlier than the teaching time planned for this activity expires. The teacher can resolve such a situation in an appropriate manner, by encouraging the creativity of the “fast” students. This article is concerned with the possibilities of increasing students’ activity in classes where computer simulation of electronic circuits is used. Using a particular example of a simulation experiment, it shows one possible option for how to engage students in the classwork. To achieve this, the function of “fault”, available in the majority of electronic virtual computing labs, is used. This feature allows a teacher to assign one of three possible errors to a selected component; students have no direct way to find out which component is faulty. To resolve the problem, they must use their own creativity and effort, their own ideas, knowledge, and skills, and the tools that they have available in the electronic laboratory.

Keywords

simulation model, educational experiment, electronic circuit, creative activities

Introduction

Nowadays, there is no doubt that simulation should be part of the educational process. After all, a computer simulation provides a unique method of investigation (Hartmann, 1996), which makes it possible to verify the behaviour of models of unreal situations or situations difficult to perform (Michalík, 2014). The computer simulation model must be created in such a way that it can be executed on a computer. To achieve this, special programming environments are used; in the field of electronics, virtual electronics labs can be used. These laboratories comprise a great number of models of real discrete components that are used to build up a macro model of an entire circuit.

In its most general meaning, a simulation is understood as a process running on a computer (e.g., Hartmann, 1996). Therefore, the term “computer simulation” has become a set expression. In the field of research and development, simulation plays a significant role, as it makes it possible to verify a circuit design before building up a prototype of an electronic system. This method makes it possible to effectively verify the behaviour of a circuit under various conditions and situations which are very difficult or complex to perform in a prototype circuit. While some concepts rigidly distinguish between the terms “modelling” and “simulation” (e.g., Křivý, Kindler, 2003), at present “simulation” is often the only term used (e.g., Hubálovský, 2011), comprising the creation of a computer simulation model, including conceptual ones. In the educational process, a simulation has the potential to develop the creativity of students and can also be applied in project teaching (Kratochvílová, 2006), (Maňák, Švec, 2003).

The advantages and disadvantages of computer simulations are generally listed by Sokolowski and Banks (2009). From the point of view of the educational process, the main advantage is considered to be the fact that the simulation makes it possible to shorten or to accelerate the behaviour of processes and phenomena, that is, to influence the real time of the simulation, thus to contribute significantly to achieving educational objectives.

Simulations in Classes

Running classes in virtual electronics laboratories makes the teaching and learning process to a certain extent unique. What makes it specific is predominantly the fact that in classes, students work with models of electronic systems (models of the particular discrete components, partial or complete circuit arrangements) and the accuracy of simulation outputs depends to a certain extent on the quality of the models.

Another fact making the model-assisted teaching unique is the educational simulation model being structured to meet specific educational objectives. To illustrate, educational simulation models will look one way if the educational objective to be achieved is to comprehend and verify their working principle, and another way if the focus lies in specific properties. While in the first case, ideal models of components will be used in the circuit structure, in the other case, a model of a real component will be selected from the component library.

Modern simulation programs for electronics incorporate some functions which were not primarily created to be used in classes, but can facilitate the process of building the macro-model of a circuit, i.e. the process of its wiring, and also some functions which can be useful to increase students' activity in classes (Michalík, Benajtr, 2014). For instance, the following functions can be used in classes: circuit wizards, the function of “Electrical Rules Check”, serving as a check of the assembled circuit, and the function of “Fault”, allowing the teacher to assign a fault to a particular component.

Active Learning

Maňák (2012) defines active learning as a method of instruction which emphasizes students' direct involvement in the teaching process, their active thinking, their active engagement in classwork activities, the classwork activities themselves and finding solutions to problems.

Active learning lies in students' individual approach to learning. In this student-centred approach, the teacher adopts the role of a guide, guiding, controlling and helping students to achieve the desired target. The students' activity is understood as an intensive activity based on both the spontaneous interests of students and their conscious effort (Maňák, 1998).

The active learning methods successfully applied nowadays are the heuristic teaching methods (Maňák, 2012). They can be based on the principle of searching for the correct way using the method of trial and error. Active learning methods exploit the existing knowledge and skills of students and at the same time, increase and deepen them. Active learning may also involve project-based learning in groups (Rohlíková, Vejvodová, 2014), (Kratochvílová, 2006).

The objective of the active learning approach is to increase the students' existing level of knowledge and skills through students' work done on a voluntary basis, spontaneously and independently. These principles are also fully applicable in students' active approach when creating models in simulation programs and environments (Šimandl, Vaniček, 2015).

Educational simulations develop many key competencies of students, learning competence in particular, because students are able to apply their theoretical background knowledge to create educational simulation models. Students also develop competence in problem-solving. Communicative competence is not neglected either, as students are able to interpret the results of simulation experiments.

Case study: “Fault” Function promoting Active Learning

Most virtual electronics labs enable teachers to assign some particular faults to individual components. The teachers in fact simulate errors that may happen in components of an actual circuit. By setting the faults, teachers can indirectly test students' knowledge and skills more deeply. In addition, teachers can re-engage the “fast” groups of students that meet the targets and achieve the intended educational objectives earlier than the teaching time planned for the activity expires. Faults can be assigned either to individual components or they can be generated automatically over the entire circuit. All these settings are saved in the same file as the circuit itself. The function of “fault” can be used to set follow-up tasks and further encourage the creativity of fast finishers. These fast groups of students should not be “left to their fate”; it is desirable to focus the students' creative ideas in the right direction. The teacher adopts a role of an advisor, helping students to achieve the newly set educational objective, i.e. to discover why the electronic circuit does not work, which component is faulty and in what way.

In order to prevent students from going to the settings dialog window to find out about possible faults assigned to a component, it is possible to hide or lock some of the program settings and functions. It is desirable to hide the component faults by using the function of “Hide component faults”. The task can be made more difficult by hiding component values, locking subcircuits, disabling the toolbar of instruments or disabling all possible changes to the circuit (i.e. the functions of Hide component values, Lock subcircuits, Disable instruments toolbar and Schematic read-only). All this can be used in classes in order to meet students' needs and to promote active learning even further. The simulation program Multisim NI allows the teacher to select a component and assign one of three possible faults to it. The component can be set

“Open”, which means that the circuit is open due to a loose connection on the component terminal. Another type of fault that can be set is a “Short” or “Leakage”, which is a fault related to partial conductance, which can be further specified by setting the amount of resistance between the individual terminals. All these simulated faults may occur in an actual circuit.

Fig. 1 shows a dialog window of the Multisim NI program at the instant of setting the fault. The selected component, an operational amplifier in this case, is being made faulty by setting a “short”-type fault between its inverting input terminal and its output terminal. The option of “None” is checked if there is no fault assigned to the particular component. In addition to the settings described above, the virtual electronics lab makes it possible to disable the individual types of circuit analysis, so that students cannot do them. In order to prevent cancelling or changing the limitations being set, the teacher can password-protect this dialog window. The password is saved to the same file as the simulation model.

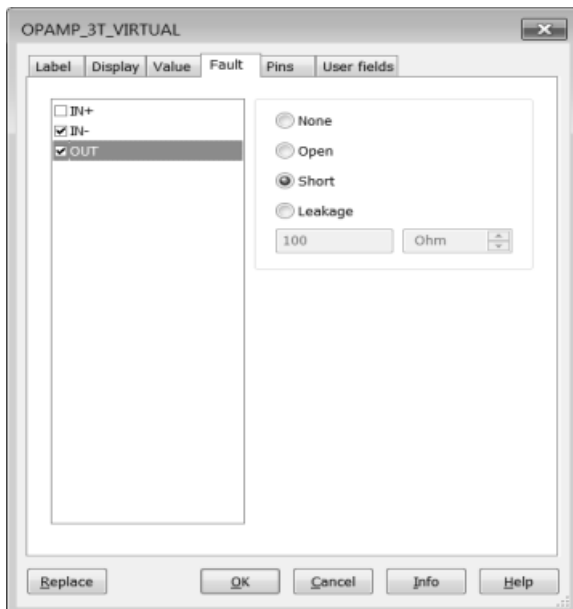


Fig. 1: Dialog window of the Multisim NI program at the instant of setting the fault

Fig. 2 depicts an example of a diagram of a push-pull amplifier with complementary transistors and a split voltage source. The output devices are represented by T2 and T3 transistors and are fed from the pre-amp represented by the T1 transistor. The simulation model was created in the Multisim NI program.

The “open” fault type is assigned to the T2 transistor of the output device. The input signal is generated by a function generator, which generates an alternating signal of a harmonic waveform. Its parameters can be found in Fig. 2.

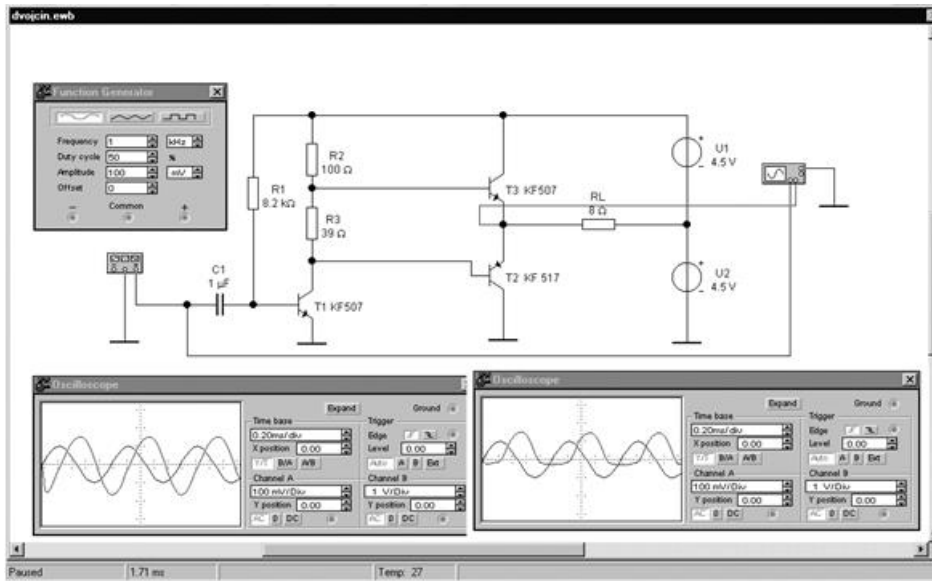


Fig. 2: Example of a diagram of a push-pull amplifier with complementary transistors and a split voltage source

The oscilloscope on the left displays the waveforms of the input and output signals before setting the fault. The oscilloscope on the right shows how the fault affected the output signal. In order to make the readings clearer, it is possible to distinguish both the waveforms in colour by colouring the conductors supplying the individual oscilloscope channels.

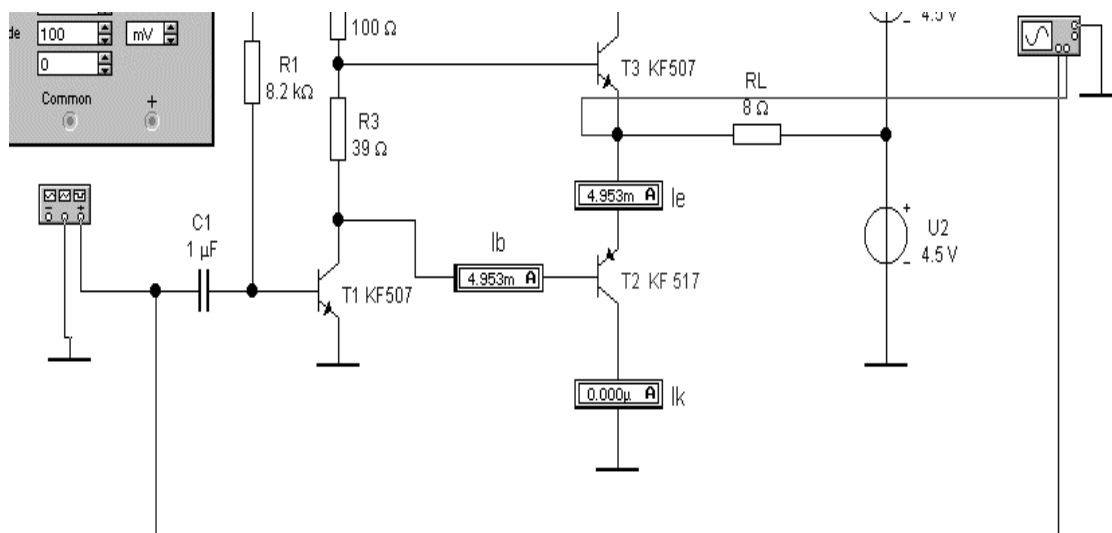


Fig. 3: Measure the currents passing through the electrodes of the “suspect” transistor

In this case, students are allowed to use all measuring instruments available in the virtual electronics lab. In order to find the fault, students should gradually measure currents passing through the individual transistor electrodes in the output device and verify if the transistor characteristic equations are valid. In this case, finding the fault will probably not be a problem because the output signal waveform displayed on the oscilloscope clearly indicates that the amplifier does not process the negative half-wave of the signal. Students might therefore consider

the T2 transistor to be faulty. One method students can use to confirm their assumption is to measure the currents passing through the electrodes of the “suspect” transistor, as shown in Fig. 3. The T2 transistor exhibits zero collector current and its base current is the same as its emitter current. This confirms the assumption that the T2 transistor is faulty.

Another way to increase students’ activity when simulating the behavior of electronic systems is to fiddle with the models of the individual components. For instance, it is possible to modify the parameters of the existing components, thus creating a model of a new component. Or, a selected component can be set “faulty” by setting some of its parameters beyond the value limits listed in the component datasheet. Such a component then does not exhibit any of the three types of fault described above, but still its behavior does not correspond to the information in the component datasheet. This method can lead to active learning and encourage students’ creativity through searching for a non-standard component.

To illustrate, Fig. 4 shows the parameter modification of the current amplification factor of the BC338 transistor. One of the amplification factor interval limits, represented in the model by the hFEmin parameter or the hFEmax parameter, can be set far beyond its datasheet limits. For example, it is possible to set the hFEmin, i.e. the lower limit of the amplification factor, to 10. This value is ten times lower than the datasheet limit. This method makes it possible to create a new model of the component, exhibiting unique behavior. The greater the change in the parameter is, the more distinct the behavior of the circuit will be. The students’ task is to find the component with the modified parameter. This is a much more difficult problem than when using the “fault” function.

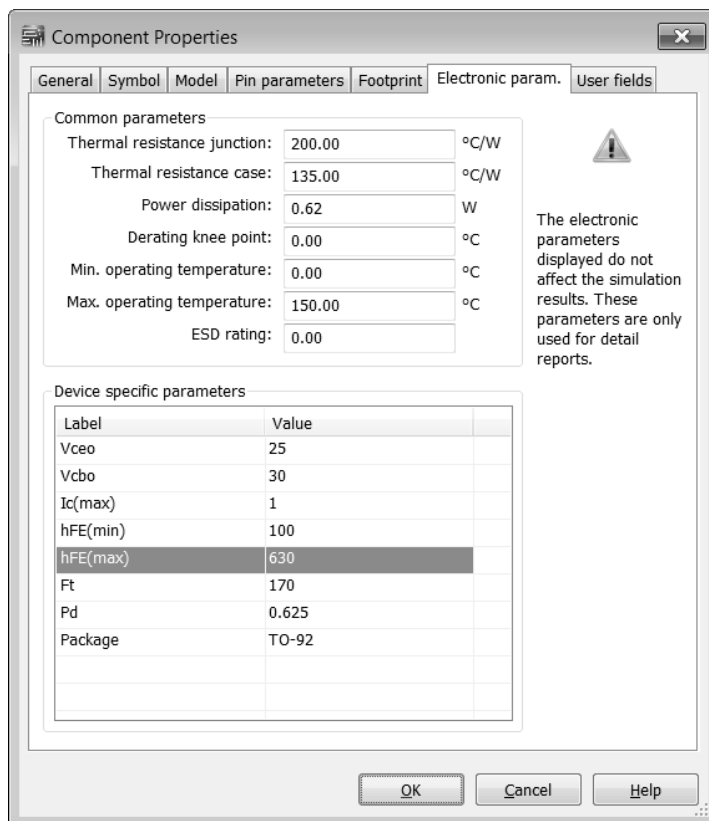


Fig. 4: Dialog window of the current amplification factor

Lesson Plan

Let us introduce here, as an example, a lesson plan including the lesson timing.

The key competencies that are developed through creating a simulation model followed by the simulation itself are primarily the following: learning competence, problem-solving competence, communicative competence and in some students, individual creative competence. What is needed is a computer work station with the simulation program installed. The particular objectives to be achieved can be described as follows: students can describe the structure of the particular simulation model and interpret the simulation results displayed, for example, as graphics output. Through a simulation experiment run with correct initial conditions, students understand the working principle of the model circuit. At the end of the class, students are assessed orally. The evaluation criterion is achievement of the intended educational objectives. The teaching approach used in the first part of the class is teacher-centered instruction, while when creating the model and performing its simulation, an individualized form of learning is used, predominantly represented by group work.

The main advantage of exploiting group work in classes is that a student is gaining knowledge through creative activities done by the entire group. Therefore, it is helpful to be familiar with group work methodology. When applying group work in classes, the whole group of students can be further subdivided into smaller groups of two or three students, for instance. Each of these subgroups can choose a speaker who controls the subgroup activity and acts as its representative. At the end of a teaching unit, the representatives of the individual subgroups report to the whole group on the solution to the set task. The division of the group into subgroups can be done randomly (thus, a heterogeneous subgroup will be formed), or according to students' interests (students will choose one of the offered topics that will fit their area of interest), or the groups formed will consist of students who are friends (these groups are denoted as amicable). Maňák (2003) finds the heterogeneous groups the most suitable. However, group work also has some disadvantages. It makes lesson planning more time-consuming and there is a need to divide the whole group into smaller groups.

The following chart shows a simplified example of a lesson plan including the lesson timing. The allocated teaching time comprises two teaching units, both 45 minutes long. The target group consists of secondary-school students in the field concerned with electronics, currently in their third year of study. The topics of the two teaching units are the creation of a medium-difficult simulation model, followed by the simulation itself, including the appropriate interpretation of the simulation outputs. The expected learning outcomes are the following: students understand both the structure of the model created and, based on the simulation, also the working principle of the circuit created.

Timing (min)	Lesson Content	What Teacher Does	What Students Do	Teaching Methods/Forms
3	<i>Introduction</i>	<i>Informs students about the educational objectives</i>	<i>Ask questions regarding the objectives</i>	<i>Discussion/ teacher-centered instruction and individual work</i>
15	<i>Specific educational simulation model</i>	<i>Presents the background regarding the creation of the educational simulation model</i>	<i>Ask questions regarding the presentation</i>	<i>Presentation and discussion</i>
25	<i>Creation of the educational simulation model</i>	<i>Walks around the classroom and helps students to build the model</i>	<i>Work independently on the simulation model</i>	<i>Individualized form of teaching</i>
14	<i>Setting the initial conditions for the simulation and the simulation itself</i>	<i>Coordinates the students' work</i>	<i>Work independently in the environment of the simulation program</i>	<i>Individualized form of teaching</i>
13	<i>Interpretation of the simulation outputs</i>	<i>Checks the results of the simulation for errors, encourages students to achieve the educational objectives</i>	<i>Interpret the simulation results, if need be, the graphics outputs, etc.</i>	<i>Individualized form of teaching</i>
15	<i>Re-engaging fast finishers; finishing the model and the simulation by the other students</i>	<i>Re-engages some students by using the Fault function, for example</i>	<i>Some search for the faulty component; others finish the model and interpret the simulation outputs</i>	<i>Individualized form of teaching</i>
5	<i>Summary of the unit</i>	<i>Evaluates the class; uses the simulation outputs to highlight the educational objectives achieved</i>	<i>Listen to the teacher; if need be, answer teacher's questions</i>	<i>Teacher-centered instruction</i>

Conclusion

The aim of this article is to demonstrate ways of engaging students in classes where simulations in a virtual educational electronics lab are used. The need for re-engaging fast finishers occurs when some students meet the targets and achieve the intended educational objectives earlier than the teaching time planned for this activity expires. An illustrative example is used to demonstrate the application of the “fault” function, which is available in most virtual electronics labs, for re-engaging fast finishers. When working with the simulation program, students are not limited by the number of components or measuring instruments, such as ammeters and voltmeters. However, there might be some limitations in the number of such types of component that comprise ready-made simulation models. Although there are tens of thousands of component models, sometimes the required type is missing. Nonetheless, a model of an equivalent component might be available. It is also possible to modify the parameters of the existing model, thus coming close to the model of the desired component.

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