

A Switching-Mode Power Supply Design Tool to Improve Learning in a Power Electronics Course

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Abstract—The static design of ac/dc and dc/dc switching-mode power supplies (SMPS) relies on a simple but repetitive process. Although specific spreadsheets, available in various computer-aided design (CAD) programs, are widely used, they are difficult to use in educational applications. In this paper, a graphic tool programmed in MATLAB is presented, which allows students to apply and to reflect upon the knowledge acquired in theoretical classes. This tool has been successfully employed in the course “Sistemas Electrónicos de Alimentación” in the Telecommunications Engineering degree as part of a project in new education methods (University of Oviedo project PB-08–019). During practical sessions, the students used the tool to design a SMPS, achieving better learning results than was the case without the tool. In addition, the tool was successfully used to improve the students’ theoretical knowledge of the subject.

Index Terms—Computer-aided engineering, education, educational technology, learning, project-based learning, switching power supplies teaching.

I. INTRODUCTION

TELECOMMUNICATIONS engineering is a five-year degree program in the University of Oviedo (Gijón, Spain). The courses that make up this degree cover topics that range from the mathematical background of telecommunications to electronic design with special emphasis given to radio and to high-frequency designs. Computer networks and computer science also feature prominently. During their last year, the students have to choose between various elective courses in order to specialize. The course “Sistemas Electrónicos de Alimentación” (“Electronic Power Systems”) [1] is one of these elective courses offered. Its main topics are the typical topologies of ac/dc and dc/dc switching-mode power supplies (SMPS), magnetic design, and power devices. Only these types of conversions are covered in this power electronics course because they are the most common in telecommunication equipment.

Manuscript received May 21, 2009; revised November 17, 2009; accepted March 11, 2010. Date of publication April 15, 2010; date of current version February 02, 2011. This work was supported by the University of Oviedo under the project in new educational methods: PB-08–019.

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Digital Object Identifier 10.1109/TE.2010.2046490

From their courses, students can learn a great deal of telecommunications theory, but they are rarely offered the opportunity to work on the development of a real product, either software or hardware. However, the ability to apply their knowledge in a real situation is one of the most necessary skills that an engineer must have. A training in the development of a real product gives the students the opportunity to face some of the real problems they will encounter in their future careers. One of the better ways to learn something is by the methodology often known as *learning by doing*: To learn something properly, you must actually do it yourself. That is the reason why the teachers giving the course offer the students the opportunity to build a full SMPS so they can apply the knowledge acquired in theoretical classes.

In order to accomplish these objectives, a lot of preliminary work has to be done: Students should learn all the theory behind the development of ac/dc and dc/dc power converters before working on a real one. This is explained in theoretical classes that cover all the aspects involved in the design: the specifications of the semiconductor devices, the design of magnetic components, the static and dynamic models of the converters, and so on. The students have to pass an exam on those theoretical concepts and must demonstrate that they have understood all the concepts taught by developing a simple spreadsheet to analyze a converter not covered in class. This spreadsheet is often done in MATLAB. The last, but not the least significant, part of the course is the design and construction of the power supply, where they have to apply all the theoretical concepts they have learned. This paper is focused on this point: the proper design and construction of an SMPS during the practical sessions of a course.

One of the main problems of making real power supplies in power electronics courses is the time that must be spent on the laborious calculations needed. These are based on static models of power supply topologies, widely known and referenced in [2]–[5]. These models are fundamental for correctly comprehending how switching power supplies work, and they are explained in the theoretical classes of power electronic courses. However, these models imply numerous calculations that take a lot of time. This makes it very difficult to complete a power supply design during the theoretical sessions of the course. Thus, design time must be optimized. This could be achieved by using computer programs. Traditionally, designers have written specific spreadsheets for every task needed in the design process. Some of these are used for the static design, others for the estimation of efficiency, and others for the magnetic components needed. These spreadsheets were not designed for educational purposes and are lacking in usability, so a lot of time is spent getting used to the tool. This work

methodology cannot be used for educational purposes because of this long learning curve.

This four-month, one-semester course, as well as covering a large amount of theory, has seven 2-h practical sessions. Those teaching the course are experts in the design of SMPS who know that it is impossible to design a full power supply during the seven practical sessions. Therefore, the design somehow needs to be sped up so that the students will have enough time to think about the way the theoretical concepts are connected to the development of the practical sessions. An appropriate way to achieve this is presented here.

This paper presents a MATLAB tool for static analysis of SMPS. It is specifically designed to be easy to work with so that students can start the static design process without difficulty. Once the architecture is chosen, the student has to fill out a form with the static specifications of the power supply. The program will make all the necessary calculations and shows the results as a set of graphics and text windows. Another feature of the tool is that it allows a user to estimate losses in the real semiconductor devices in order to show students a realistic view of the work of a designer. It also provides help in taking decisions in the tradeoff between cost and efficiency. Moreover, the graphic results can help lecturers in their explanations of converter models, showing where the boundary between continuous conduction mode (CCM) and discontinuous conduction mode (DCM) lies and the evolution of the currents and voltages in the converter in relation to the power processed. In addition to the use of this tool to complete the design process, a similar tool is also included to help in the design of the magnetic elements, such as inductors and transformers.

Before the development of this tool, students were expected to build the same SMPS, but both the static design and the design of the magnetic elements were carried out by the teacher. If the students wanted to, they could check the design at home, and they were encouraged to do so. However, because of the laborious calculations involved, very few students actually checked the design themselves, therefore very few could link what they had learned in theoretical classes with the practical sessions. The idea was to provide a tool that helps to make that connection by avoiding lengthy calculations. Hence, the students have more time in practical sessions to reflect on how to apply their acquired knowledge. In the current version of the course, every student is obliged to carry out the design of the SMPS during the first practical session so that they all have a better understanding of the decisions taken in the design process. Other course objectives, like the acquisition of power electronics concepts and the static and dynamic analysis of ac/dc and dc/dc power supplies, are evaluated by an exam and the development of an original spreadsheet of a converter topology not covered in class.

MATLAB was chosen because students are used to working with it in previous courses. In other telecommunications degree subjects such as Digital Signal Processing, MATLAB is a *de facto* standard, and there are some educational tools available [6], [7]. Students know its programming language, so they can understand how the tool is made, manage their results in a different way, or improve the tool with other converter topologies (for example, the spreadsheet developed as another project in the course). There are also more tools for power electronics de-



Fig. 1. Main window.

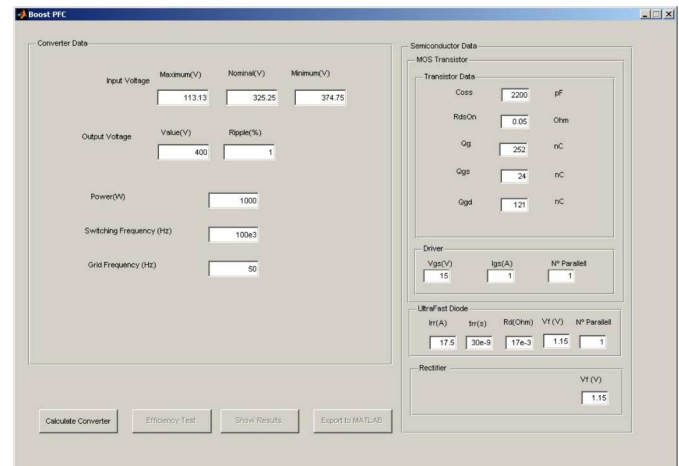


Fig. 2. Boost converter with PFC module.

sign that work with MATLAB [8]–[10]. However, they are intended for acquiring knowledge rather than applying it. There is a copy of this tool available at <http://www.unioviado.es/ate/sea/archivos/converters.zip> for evaluation purposes.

II. BASIC USAGE

Working with the tool presented here is very easy. It has to be launched from MATLAB's command line. The user has to choose which converter topology to work with or launch the magnetics tool from the main window, as shown in Fig. 1. Once a topology has been chosen, the corresponding converter module is launched. Each converter module was designed to maintain a similar appearance in order to simplify their usage (Fig. 2). The window is divided into two parts. The left side has to be filled in with the specifications of the converter, such as input and output voltage, output power, output voltage ripple, switching frequency, and so on. The datasheet parameters of the selected semiconductor devices appear on the right side; these are used to estimate the losses and the efficiency of the power supply using commercial semiconductor devices.

The entire program is controlled with just four buttons, only one of which is enabled initially. This button is called the "Calculate Converter." This takes the design data to calculate currents and voltages in every main component (transistors, diodes, inductor, and transformer) of the power converter.

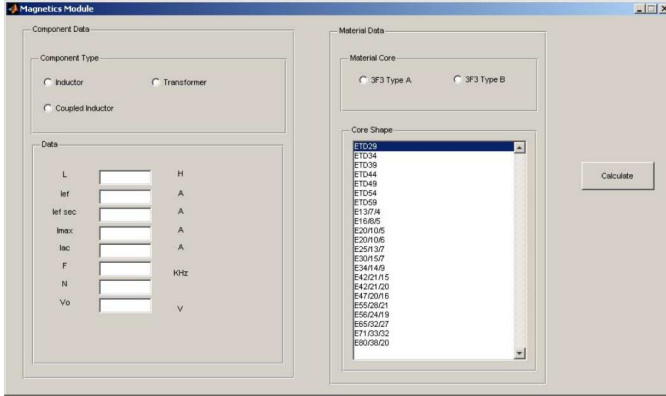


Fig. 3. Magnetics module screenshot.

When the calculations are finished, the results are shown in various graphics and text windows. Now, the button called "Efficiency Test" is enabled. With the previously calculated voltages and currents, the losses in the semiconductor devices are estimated using the datasheet parameters that were entered on the right side of the window. Graphic and text windows showing the efficiency under various conditions are shown. The next buttons are used to show all the previously calculated data and to export these to MATLAB's workspace.

Data are exported to MATLAB as a structure, where all the information shown and some other results are stored. These data include currents and voltages in every main component and switching and conduction losses. With this structure, a deeper analysis can be developed, using MATLAB's facilities. This kind of analysis can be programmed by students because of their prior knowledge of MATLAB's programming language.

Working with this tool mimics the manual design process for a SMPS power supply. First, the static calculations are carried out, in which all the currents and voltages are calculated. Then, using these results, components are selected to choose which semiconductor devices handle these currents and voltages. Thus, the designer also evaluates the losses on the semiconductor devices.

The Magnetic Elements Module is used after the Converter modules. When the currents and voltages on the magnetic element have been calculated for the chosen topology, the Magnetic Element Module can be launched from the main window (Fig. 1). There is a list of components that can be chosen for the design (inductor, transformer, coupled inductor). Only the fields necessary to complete the design are enabled for students to fill in with the data provided by the converter module. As shown in Fig. 3, the right side of the window shows a list with different materials and magnetic cores. A small database with E and ETD cores and 3F3 materials is provided. Students can complete this database with more cores and materials. The tool offers information about the number of turns, diameter of the wire, and number of wires in parallel to achieve the desired component. An estimation of the temperature reached by the magnetic element is also shown in order to help students to decide on the size and shape of the core.

The following section shows the theoretical background and an example of a CA/CC converter usually used in power supply

architecture: a boost converter with power factor correction (PFC). This is a typical converter in PFC topologies. Students will have made one of these during the course's practical sessions.

III. THEORETICAL BACKGROUND

The static design of a SMPS power supply is a well-known subject fully treated in the literature. The main references used for the development of this work, and given to the students in their lecture notes, are [2]–[5]. Following the specific set of equations for each converter topology, the program calculates currents and voltages in each component. With all this information, the losses, and then the efficiency, can be calculated. These equations, like those that set the boundary limits between CCM and DCM, those that link the duty cycle with the voltage relationship between the input and the output, and the input specifications, are explained in theoretical classes; however, they are beyond the scope of this paper.

From the current through every component, the conduction losses in the semiconductor devices are estimated by assuming classical models: A MOSFET on ON state behaves as a resistor, and a forward-biased diode behaves as a resistor connected in series to an ideal voltage source. The values of these parameters are found on the datasheets of semiconductor manufacturers and entered into the program by the students. Equation (1) shows the estimation of conduction losses in a MOSFET, where $I_{\text{effMOSFET}}$ is the effective current through the transistor and R_{dsOn} the ON state resistor. Equation (2) is used to calculate the conduction losses in a diode, I_{effDiode} is the effective current, I_{Diode} is the mean value of the current through the diode, V_{γ} is the forward voltage drop, and R_{diode} is its resistance.

$$Losses_{\text{condMOSFET}} = I_{\text{effMOSFET}}^2 \cdot R_{\text{dsOn}}(W) \quad (1)$$

$$Losses_{\text{condDiode}} = I_{\text{effDiode}}^2 \cdot R_{\text{diode}} + V_{\gamma} \cdot I_{\text{Diode}}(W). \quad (2)$$

To calculate the switching losses, the classical piecewise linear model is used [11]. This model takes into account the different parasitic capacitances that are present in both the transistor and the diode. In this case, the MOSFET and diode parameters are found on the datasheets of semiconductor manufacturers, too. These loss models are used because, while they are simple and easy to understand, they are usually used as a first approach to estimate semiconductor losses in a real design. The design of a magnetic element is usually based on finding the number of turns that minimizes losses while avoiding saturation of the core [13]–[15]. This tool is based on that principle.

Losses in the copper are calculated by estimating the resistance of the windings and the effective current through them, which are calculated in the converter modules. Resistance is estimated by the expression (3) that relates the resistance to the resistivity of the material, ρ , the mean length of a turn on the winding, l_m , which is given by the core vendors, the number of turns N , and the section of the wire S_{wire} . The section of the wire is calculated by assuming that all the window area of the coil former will be filled with copper. As it is impossible to achieve that with a wire, an approximation is used by using a

smaller window area, usually 30% of the data given by the coil former vendor.

$$R_{Cu}(N) = \rho \cdot \frac{l_m}{S_{wire}} \cdot N. \quad (3)$$

The process to estimate the losses in the magnetic core is a little bit more complicated. While estimating the losses in the winding is quite straightforward, losses in the magnetic core require a more complex approach. Magnetic material vendors often offer some curves relating the peak magnetic flux density with the power loss density [12], so the losses can be estimated by multiplying the effective volume of the core by the power loss density obtained from the curves. These curves were parameterized and programmed in the application. Equation (4) shows the parameterization used, where B_{peak} is the peak magnetic flux density, f is the frequency, and c , x , and y are constants depending on the material chosen. Peak magnetic flux is calculated using the expression in (5), which relates the value of the inductance L , the peak ac component of the current I_{ac} , the number of turns N , and the effective section of the core A_e , with it.

$$Losses_{material}(B_{peak}, f) = c \cdot f^x \cdot B_{peak}^y \left(\frac{kW}{m^3} \right) \quad (4)$$

$$B_{peak}(N) = \frac{L \cdot I_{ac}}{N \cdot A_e}. \quad (5)$$

The losses are a function of the number of turns, therefore the optimal number N has to be chosen. The process is to set N as the number of turns that minimizes the overall losses, as can be seen in Fig. 12 where the losses on an inductor are depicted. However, saturation of the core must be avoided. This is checked by comparing the expression in 6, where I_{max} is the maximum current through the winding, N the number of turns, A_e is the equivalent area of the core, and L is the value of the inductance, with the maximum magnetic flux supported by the core, shown in the datasheet of the material.

$$B_{max}(N) = \frac{L \cdot I_{max}}{N \cdot A_e}. \quad (6)$$

Due to the switching frequency used in the SMPS studied in the course, the skin effect has to be taken into account. The skin effect describes the way in which current flows through the outer part of a wire. With increasing frequency, the current tends to flow through a smaller area, and then the resistance and the losses increase. The tool calculates the skin depth and offers advice about the optimum wire diameter and the number of wires in parallel to configure a *litz* wire that can handle all the current that has to flow while avoiding the skin effect.

These are the kinds of facts that the students learn in the theoretical classes. What this tool offers is a way to make the calculations faster and then improve the practical sessions, where the students can apply all the knowledge they have gathered in theoretical classes.

IV. EXAMPLE OF A BOOST CONVERTER WITH PFC

As an example, a boost converter with power factor correction was designed using this tool. Students made a low-power SMPS



Fig. 4. Results on boost PFC converter.

power supply in the practical sessions for reasons of safety. The boost converter specifications are the following:

- Minimum Input Voltage: 80 V RMS;
- Maximum Input Voltage: 265 V RMS;
- Nominal Input Voltage: 230 V RMS;
- Output Voltage: 400 V;
- Output Voltage Ripple: 1%;
- Output Power: 1000 W;
- Switching Frequency: 100 kHz;
- Grid Frequency: 50 Hz.

All of these specifications are entered in the fields on the left side of the module window, as seen in Fig. 2. There are several ways to calculate the inductor; one of the most common is to fix the limit between CCM and DCM. Here, it is fixed to half the power handled, 500 W. A window showing the results of the static design (Fig. 4) appears as soon as the first button, “Calculate Converter,” is clicked. Some useful data for choosing the semiconductor devices, such as maximum voltages and maximum effective current on both the transistor and the diode, are shown. The inductor and capacitor values and the maximum and minimum duty cycle are also provided.

Currents through the most important elements—namely the inductor, transistor (Fig. 5), and diode (Fig. 6)—are plotted against the conduction angle $w_L \cdot t$, where w_L is the linear angular frequency of the mains. With this information, it is possible to find devices that can meet the specifications and then evaluate the resulting efficiency. The MOSFET transistor SPW47N60C3 and the UltraFast diode STTA2006P were chosen as an example. Real specifications, taken from datasheets [16], [17], were entered on the right side of the window (Fig. 2).

There are also fields to enter the driver current and voltage and the number of transistors and diodes in parallel. Putting devices in parallel is a usual arrangement to reduce current stresses and conduction losses, so it has to be taken into account for the estimation of the losses. Semiconductor losses are divided into switching losses and conduction losses (these data are not shown, but are stored in the exported structure). As seen in Fig. 7, the efficiency at the maximum, minimum, and nominal input voltages is shown by pushing the “Efficiency Test Button.” This level of detail helps students to see actual problems in power supply design, such as the tradeoff between efficiency and the number of devices in parallel. Fig. 8 explains this concept by plotting efficiency versus the number of devices in parallel, which is directly related to cost.

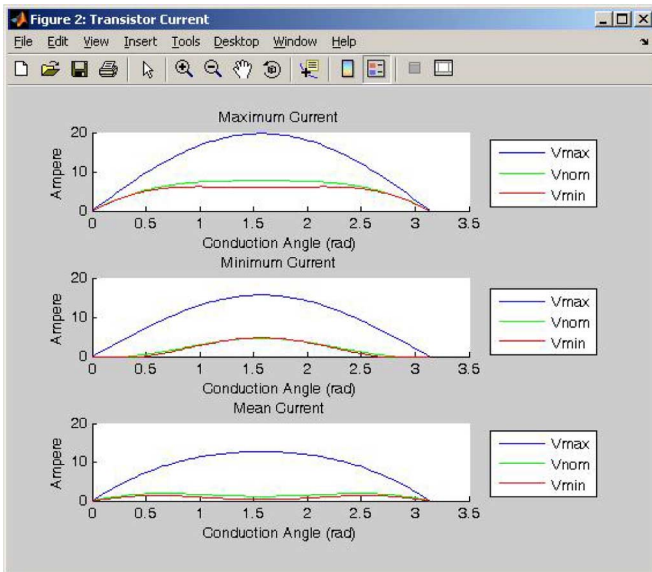


Fig. 5. Currents through the transistor in the designed boost converter.

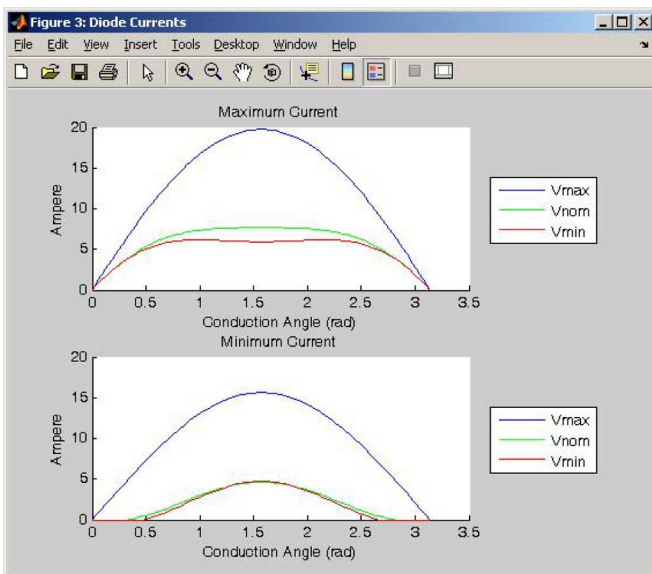


Fig. 6. Currents through the diode in the designed boost converter.



Fig. 7. Efficiency of the boost converter.

V. EXAMPLE OF AN INDUCTOR

As an example of how the Magnetic Module works, the inductor needed by the previously described boost converter will be explained.

Once the magnetic module has been launched, the user must choose what type of magnetic element to design. In this case,

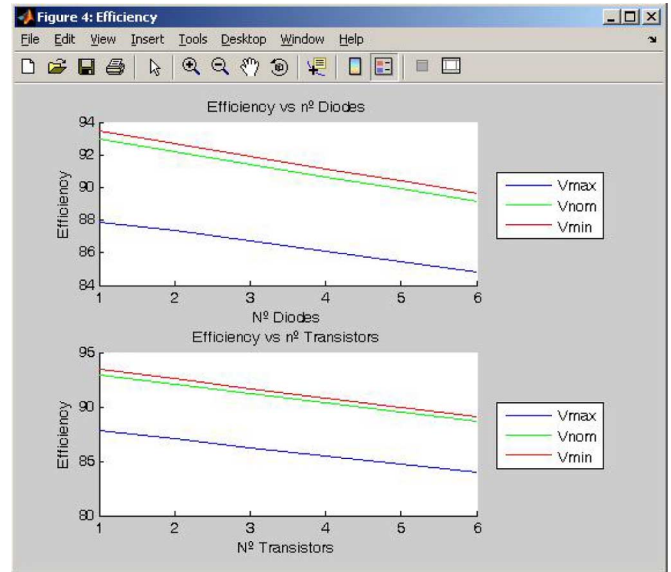


Fig. 8. Efficiency of the boost converter versus the number of devices in parallel.

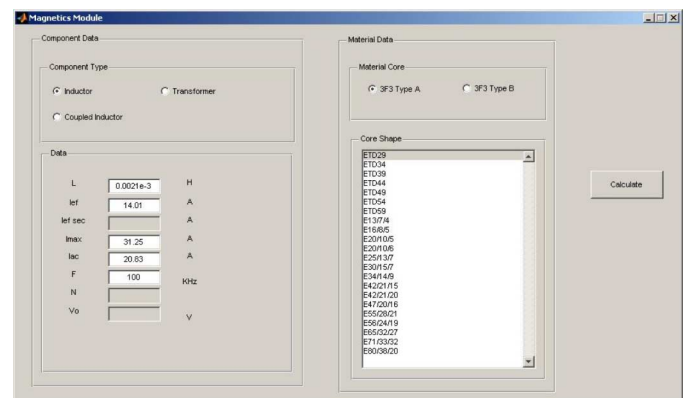


Fig. 9. Magnetics module screenshot with data for the inductor.

the inductor was chosen, and the application activates the fields that need to be filled in to design the component, as can be seen in Fig. 9.

These data must be taken from the information given by the results from the chosen converter design module. This was a boost converter in the previous example. The value of the inductor was taken from the text window that shows the converter parameters (Fig. 4), while the various values for currents were taken from the graphics that show the boost converter's inductor currents (Fig. 10). Once the fields have been filled in with these data, the material and shape of the core must be chosen. Currently, only two materials and a variety of E- and ETD- shaped cores are offered, but this database can be enhanced with more cores and materials. This database stores the data needed to calculate the magnetic behavior of the core, information that is offered by magnetic material vendors in their datasheets.

After all the fields have been filled in, the user must click the "Calculate" button. The program brings up a text window (Fig. 11) with the number of turns, the size of the gap, an estimation of the temperature reached by the inductor, the diameter

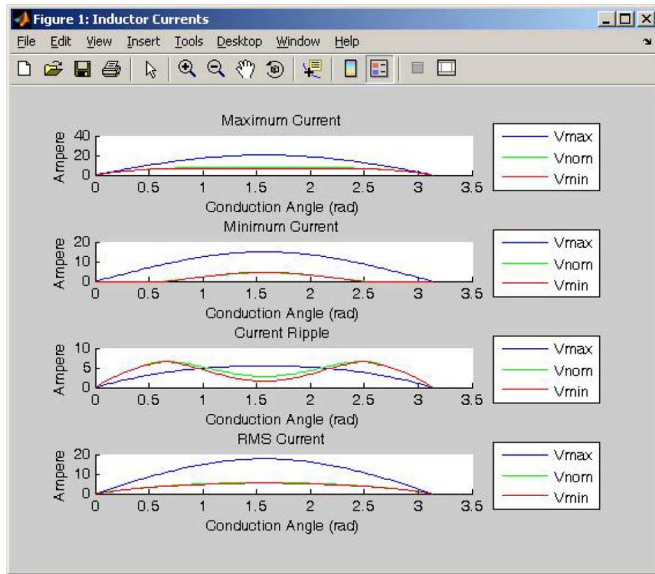


Fig. 10. Currents through the inductor in the designed boost converter.



Fig. 11. Data for making the inductor.

of the wire to avoid the skin effect, and the number of wires in parallel needed to carry the desired amount of current.

A picture (Fig. 12) showing the evolution of the losses along the number of turns is also shown. This picture shows the difference between the losses in the copper, due to the resistance of the winding, and the losses in the core, due to the current ripple.

Figs. 11 and 12 provide a visual feedback for their design. As can be seen, several magnetic designs can be made for the same specifications. Students have to assemble the best option.

Using this tool, the lengthy process required to design of a magnetic element is shortened by the use of the computer. The calculations involved in the manual process are not too difficult, but there are a lot of small details concerning the parameterization of the behavior of magnetic materials and the shape of the core that are critical. Making a mistake in these details is almost totally avoided by all of these data being taken from the database.

VI. EDUCATIONAL BENEFITS

It is important to note that the tool is not designed to teach power electronics concepts. Students should acquire their knowledge in theoretical classes, and this should be evaluated by the exam and the theoretical project (the spreadsheet they are required to make). The purpose of this tool is to enhance the application of the knowledge acquired in theoretical classes

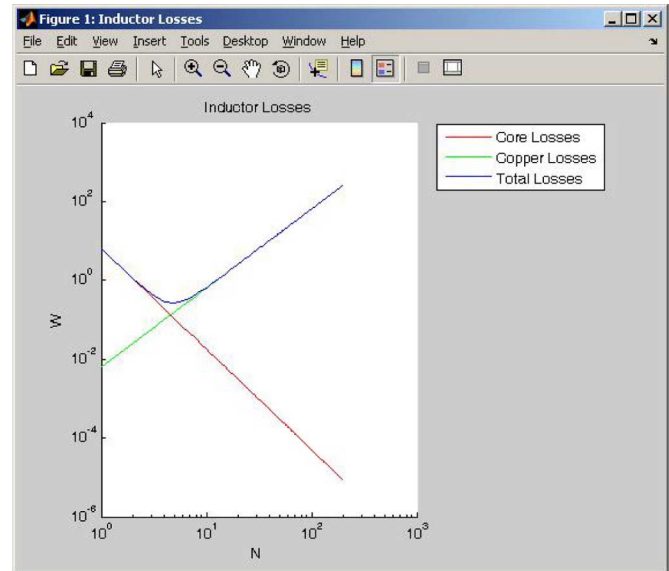


Fig. 12. Losses in a magnetic component.

during the practical sessions, where students design and build a SMPS. The objective of the use of this tool in practical sessions is to create a connection between theoretical concepts of power electronics and their practical application. This new situation facilitates the correct comprehension of the knowledge acquired and significantly enhances learning.

The main educational characteristics of the tool presented here are that it does the following.

- Shortens the time needed to design and build a SMPS in practical sessions. Therefore students have more time available to relate theoretical concepts to the practical problems presented in design sessions.
- Shows the results of the static study in a user-friendly way. This improves the assimilation of theoretical concepts because this tool can be used to evaluate the evolution of the power supply behavior while changing design parameters.
- Allows students to see the process they will follow in the practical sessions. The way they use the tool resembles the design process usually followed by SMPS designers as a first approach.

Before this tool was available in the practical sessions of the course “Sistemas Electrónicos de Alimentación,” students still had to make the same SMPS power supply. As the lecturers involved realized that the available time was not sufficient for students to complete the entire design process, they themselves carried out both the static design and the magnetic elements design. Students were expected to check this design at home, but very few of them did so. In fact, during the practical sessions, the students only assembled the converter, but they did not realize why the specific component values were chosen. Only the better students who were willing to spend time at home checking the design really understood the whole process. In order to solve this problem, the lecturers introduced this tool, which allows the static design to be carried out by the students in their practical sessions. This means that all the students know why each component was chosen and therefore develop a better understanding

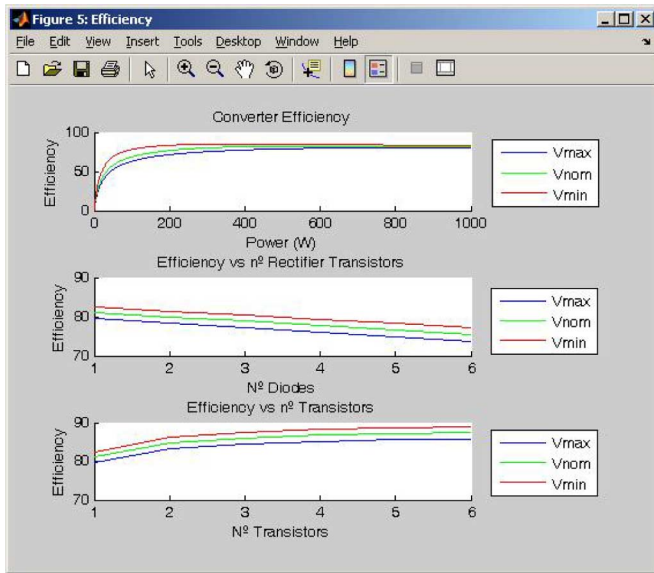


Fig. 13. Efficiency of a half-bridge converter.

of the overall design of a SMPS power supply by applying their power electronics knowledge.

Next, a few features that a good student can use to improve their knowledge will be introduced.

- By varying the power ratio at which the power supply changes from CCM to DCM, the student will see how this affects the efficiency, as well as how this new value of inductance affects the physical values of the magnetic element that is needed.
- A similar study can be performed by varying the switching frequency. While increasing the switching frequency, the values of the inductor and the capacitor needed to meet the voltage ripple requirement decrease, but the switching losses increase.
- As the tool allows the real semiconductor parameters to be varied, the student can see how a better transistor or diode improves the efficiency of the power supply.
- Other important facts shown are the efficiency represented versus the number of semiconductor devices in parallel, as in Fig. 13, which is a representation of efficiency versus cost. This can help the students to make decisions about some of the various tradeoffs in this application, which is one of the most important skills for an engineer.
- By referring to Fig. 13, a lecturer can easily explain the evolution of efficiency versus the power processed. As can be seen at low power, every loss represents an important decrease in efficiency. As the power increases, the efficiency will increase until the power is so large that the currents involved imply major conduction losses.
- While the tool is designed for the static design of the converter, students can export the data to MATLAB and then build the dynamic model with the actual values of the components. Using the tools provided with MATLAB and the data from the application, students can display Bode diagrams and design the control for its power supply. Another useful improvement of the tool will be its integration with

a control design tool, for either analog or digital control. An example of the capabilities of MATLAB to deal with control and power electronics can be seen in [18], where MATLAB is combined with SPICE simulations to develop a system identification program.

- Using this tool, the magnetic design time is improved, and graphics like the one on Fig. 11 are shown. These graphics are very similar to the ones shown in the lecture notes, but with this tool, students can see how they vary with the different cores used and can better understand how the size and shape of the core is involved in the design. As the magnetic elements are usually handmade, the less time the students employ in their design, the more time they will employ in the construction of the component, which is a manual skill that has to be learned in the practical class. This construction process involves various details, such as the way of carrying out the winding and how to make the *litz* wire, which take a lot of time for a class with many students. In fact, the magnetic design session became more intuitive and practical.

Nevertheless, it is important to keep in mind, as the students appreciate, that the tool works with simplified but accurate models. These models will not reflect all the effects involved in the actual behavior of SMPS, although they are widely used in designing SMPS as a first approach.

A much more detailed process can be followed by the use of simulation tools as pSPICE [19]. The waveforms acquired will be much more accurate. However, working with a simulation program is quite difficult and requires a lot of training in using the program. One of the worst drawbacks of simulation programs is the dependence on the vendor's models for the semiconductor devices. The use of idealized models can help, but this brings a lack of accuracy similar to that seen from the use of simplified models. In this case, the idea was to motivate the students with a real project. In fact, students prefer to handle real devices rather than a simulation tool in a computer, as they do in so many courses. Other possibilities are to include simulations on the development of the prototype, but this was not possible due to the limited time available. Nevertheless, while it is impossible to neglect the power of circuit simulation programs, for the reasons stated, the use of these simulation programs is recommended only for long-lasting projects such as Master's theses, not for intensive use in practical courses such as that taught by the authors.

Another approach is the use of computer-aided learning programs, such as those described in [20]. These are designed to teach the fundamentals of power electronics, as taught in theoretical classes. A good compromise between the theoretical and practical approach is the tool described in [21], which helps in the design while showing the waveforms on the different elements. However, although this is good for teaching purposes, it is not focused on the design of a SMPS, which is the goal of the practical sessions.

VII. RESULTS

To evaluate the actual success achieved by the use of this tool, the authors analyzed the results achieved by the students. The

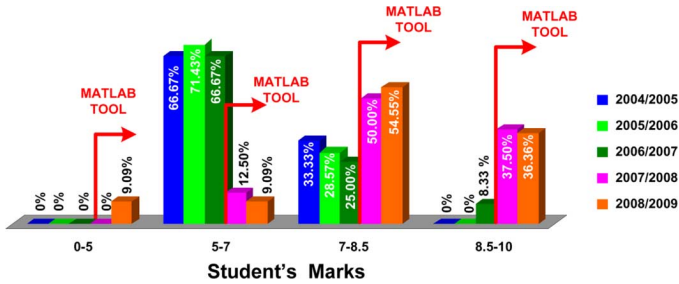


Fig. 14. Marks obtained in the subject versus time.

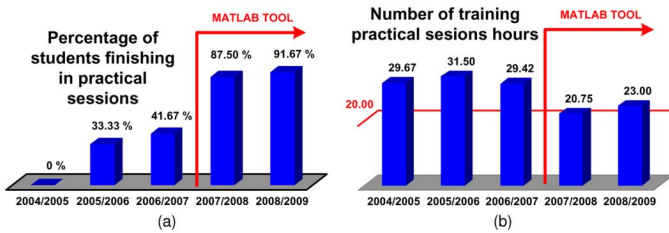


Fig. 15. (a) Percentage of students who finished the converter in practical sessions. (b) Hours used in training for the practical sessions.

evaluation method of the course “Sistemas Electrónicos de Alimentación” is fully described in [1] and has not changed since the course was first offered.

The students fail if they get less than 5 points, and the top mark is 10 points. These marks are grouped in four intervals, which represent the actual qualification that is delivered to the student. Fig. 14 shows the marks obtained by the students from 2004–2009. As it can be seen in Fig. 14, although most of the students passed the subject, the percentage getting the highest marks increased significantly with the introduction of the tool presented in this paper.

The most common mark is between 7 and 8.5, which is quite high. In previous years, most students got a mark between 5 and 7, with 5 being the lowest mark needed to pass the subject. Thus, there is a significant improvement in the students’ learning of power electronics because they assimilate theoretical concepts and are able to apply them to the practical sessions. It can be inferred that exam marks and the results of the theoretical work (the spreadsheet they are required to create) increase because a student must apply his or her knowledge in order to obtain significant learning.

Some other benefits are shown in Fig. 15. The greatest part of student’s grade is obtained by their building a switching power supply during the practical sessions of the course. Before the use of the tool, there were many students who could not complete this in the time available in the practical sessions [Fig. 15(a)]. Those students needed to spend more hours in the laboratory, which was problematic for them. The other benefit is reflected by Fig. 15(b), which represents the number of hours needed by the students to prepare the practical sessions at home. With the aid of the tool presented in this paper, it has become closer to the 20 h that the lecturers had planned, as the project on the SMPS cannot interfere with work on other courses.

It can be argued that the students’ grades are not a good metric to evaluate their degree of learning. However, the main part of a student’s grade is awarded for the way s/he has worked on

the SMPS power supply [1]. A good student who made his or her power supply work without any help and can explain to the teacher every part of the design process will get the highest mark. As all the students are now able to accomplish the proper design and building in the proposed practical sessions, their marks had increased, as reflected in Fig. 14.

The results of the use of the tool presented in this paper are also reflected in the periodical surveys made by the University of Oviedo to assess the quality of their degrees. In those surveys, the students are asked to rate different aspects of the courses and then give an overall score. This process is repeated with all the courses of the degree. In Fig. 16, the results of the course “Sistemas Electrónicos de Alimentación,” in which this tool has been used, are shown with respect to the average results from all the courses of the degree in Telecommunications Engineering.

Prior to the introduction of the tool presented in this paper, the course was rated similarly to other courses. Since its first use in 2008, the course has obtained higher marks for all the points evaluated. Fig. 16 shows the results of some of points evaluated in the survey, such as the way in which the practical sessions are planned [Fig. 16(a)], how students evaluate the didactical material given [Fig. 16(b)], and how they rate the new knowledge acquired [Fig. 16(c)]. Such a good rating represents an affirmation for the lecturers involved. As a result of the survey, some conclusions can be drawn: An experience like building a SMPS is very motivating, which leads to a good evaluation. A significant part of this positive evaluation is due to the fact that the practical sessions were properly planned and had a good infrastructure.

VIII. CONCLUSION

A simple but accurate tool for educational purposes has been presented in this paper.

This tool has been successfully used in the course “Sistemas Electrónicos de Alimentación” in the Telecommunications Engineering degree program at the University of Oviedo. It has helped students to design and build a power supply system (Fig. 17), saving a lot of time and enhancing their significant learning. “Sistemas Electrónicos de Alimentación” is a course taught in the last year of the Telecommunications Engineering degree.

In the practical sessions of the course, students are required to build a complete boost converter. While the converter used to be designed and tested by the lecturer, students now make one themselves to benefit from the practical application of their theoretical skills. There are seven practical sessions, each lasting 2 h. Although these practical sessions are supposed to be sufficient to complete the design and construction of the converter, in the lecturers’ experience, it is very difficult to do so. Therefore, the use of a user-friendly CAD tool is highly desirable. The tool presented in this paper met with great success in the static design process; all the students made their converter work properly and completed the entire design process. Students tested the component selection with the aid of this tool. The static design is part of the firsts practical session, while the later sessions are taken up with the design and building of the inductor, where this tool was also used, and the assembly of the power supply. All the students reported that the tool was very useful and showed an

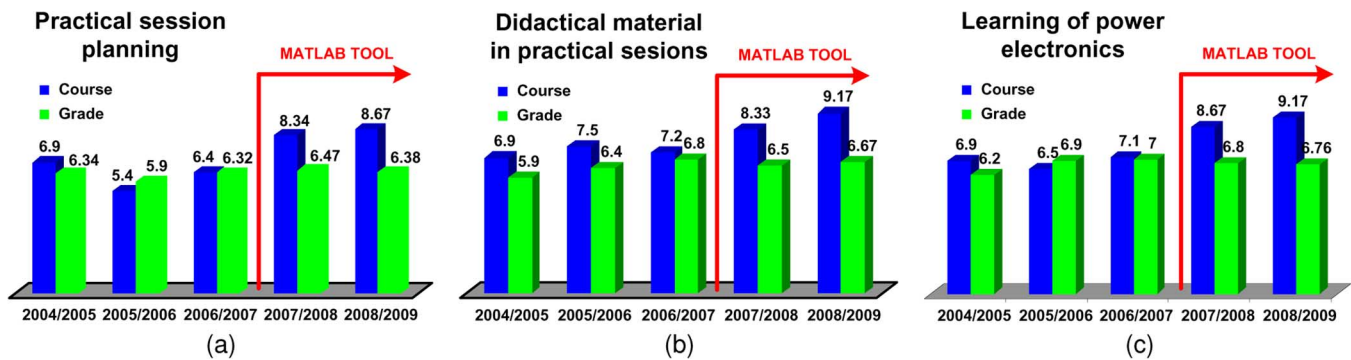


Fig. 16. Results of the survey: (a) rating of the hours needed by the students to plan the practical sessions, (b) rating of the didactical materials used, and (c) overall rating of the subject.

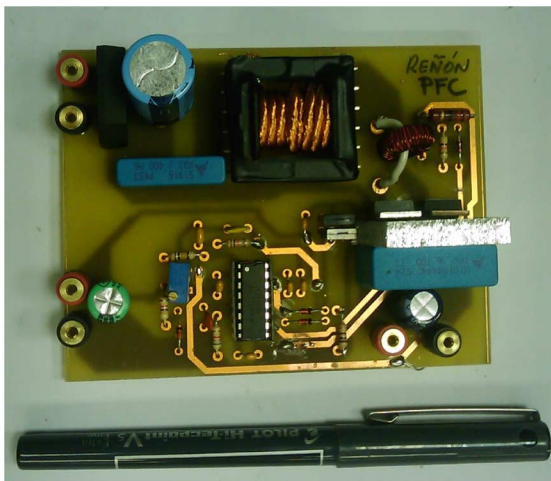


Fig. 17. Prototype made in practical sessions.

in-depth knowledge of the design of SMPS power supplies. This contrasts with the situation prior to the introduction of the tool, when the students did all the calculations by hand. Because of this lengthy process, the little reflection was shown in the quality of the design of SMPS. Therefore, this tool raises the average level of learning in the design of SMPS power supplies because it is focused creating a scenario where students are able to apply the theoretical concepts explained in lectures to designing and building a SMPS.

Although this tool is not designed to teach students how power supplies work, it does help the lecturer to explain some difficult concepts by using the graphic results obtained during the design process. These explanations take place during the practical sessions in which students have to build a full SMPS. Therefore, the objective is to connect theoretical with practical concepts to obtain significant learning by applying the acquired knowledge.

Moreover, due to the fact that this tool is written in a programming language that students should already be acquainted with, they can understand how it works and improve it or use it in different applications. Another assignment used to evaluate students in the course is the design of a spreadsheet that analyzes some aspects of a converter topology not studied in class. Students usually create this spreadsheet in MATLAB, thus facilitating integration with the tool presented in this paper.

The benefits of using this tool are reflected in the marks obtained by the students (Fig. 14), the efficiency in the building of the prototype, and the student spending less hours while there are more students who finish the SMPS power supply (Fig. 15). The results of the surveys made by the university also reflect that the students valorize the subject better than the average of the subjects of the grade (Fig. 16). Therefore, the overall quality of the student learning was improved by the use of this tool.

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