LOW COST EMBEDDED KITS FOR TEACHING POWER ELECTRONICS IN LABORATORY

Rubens Marcos dos Santos Filho Marcos Antônio da Silva Pinto John Kennedy Schettino Souza

Centro Federal de Educação Tecnológica de Minas Gerais
CEFET-MG / DEII / C.ELT
Av. Amazonas, 7675 – C.L.ELT – Belo Horizonte – MG – Brasil
CEP 30.510-000 – e-mail: rsantos@deii.cefetmg.br

Abstract – **This article presents the experience acquired with the design, construction and use of kits for power electronics laboratory demonstrations for both undergraduate and high school technical courses on electronics. The kits have been designed and built by the power electronics instructors of those courses. After a discussion about several teaching approaches of power electronics concepts, the techniques and methodology of construction of the kits are shown, which consist of using simple and low cost resources. Some of the kit's features are modularity, flexibility, robustness and good aspect, which has provided a better working dynamic in the laboratory classes. The presented ideas can be extended to other matters.**

KEYWORDS

Education in Power Electronics, teaching kit, command modules.

I. INTRODUCTION

Teaching Power Electronics is a challenging task. Such as most of the subjects of the technological field, the volume of knowledge increases rapidly, and often new technologies lead to changes in concepts and paradigms. In the academic classes environment, there is limitation of time available to the technological subjects, which in a typical undergraduate course hardly takes more than two semesters. So, the amount of subjects to be studied should be reduced, what leads the educator to ask what to teach. Even in a introductory course, it is a hard task to choose the subjects in a secure way. Moreover, the Power Electronics field is multidisciplinary, which complicates the teaching task. Its study requires previous knowledge of electrical circuits, magnetic elements and magnetic circuits, analog and digital circuits and systems, modeling, control systems, digital simulation, etc.. Also, in the case of the practical implementation of converters, if EMI/EMC rules are not observed and respected the results may be frustrating or even catastrophic.

In an effort to accelerate the subject's presentation and study, it is common the "verification" approach in the laboratory classes, where the student does a little bit more than just "observe" and register the working systems, which in most cases are almost "black boxes" like implementations. There are cases where the student finishes the power electronics course without even have seen a power electronic device.

The verification approach has its merits, but when used alone does not bring out the student's creativity, does not allow his interaction with concepts, and does not allow that he deals with power electronics systems problems. The exclusive use the verification methodology constitutes a typical case of valorization of quantity over quality of knowledge. In another way, the approach where the student acts building the whole system at the device level is not viable because it takes too much time and the circuit does not always work properly.

There is also the computer simulation resource, which is very advantageous from the feasibility and ease viewpoint, but it fits in an intermediate level between theory and practice. Often the simulation is the unique way the teacher has to proceed, since laboratory teaching modules or kits neither are available nor exist commercially.

A modern tendency is the education "by skills", which opposes to the education "by subjects". This methodology is included in the "Directives and Bases for Education" law in Brazil – LDB, of 1996. In this new methodology of teaching, the skills and competencies to be acquired by the students are focused, such as for example the aptness of analysis, of synthesis, and of diagnostics.

Perhaps a good approach would be one that mixes all the methodologies, taking the advantages of each one.

Hereafter the basic concepts adopted for the kits design and construction will be presented. The developed kits will be presented in section II.3 together with some waveform results.

II. EMBEDDED KITS

A set of kits for teaching power electronics in the lab was designed and built. The idea was motivated by the need to make viable the study of several power electronic circuits on the workbench. Moreover, the high cost of commercial kits makes its acquisition difficult or even not viable by public education institutions in Brazil. And those kits have formats and working philosophies that rarely satisfies the instructor needs. Another motivating factor was the electrical and mechanical fragility of those commercial kits, which often does not hold the required robustness to support tenths of classes per week.
Thus, the conception of the embedded kits began from the following bases:

- There should be achieved an intermediate level of fragmentation of the power electronics systems in such a way that within the available time there could exist the interaction of the student with the systems without neither the loss of intuition of the whole nor the loss of contact with power semiconductor devices.

- The kits should be low cost;
- The kits should be robust mechanically and electrically enough to support a high volume of weekly classes avoiding the need of frequently maintenance;
- The aspect of the kits should be nice.

In relation to fragmentation, the solution of dividing the kits in modules was adopted: the command module or pulse generation module, the control module, the gating module and finally the power module. Each module has on its top side synoptic diagrams which mixes electronics circuits and block diagrams, and the key points are accessible for reading the waveforms and to connect the power module to other modules.

The power modules are simple frames with interconnections, since each electronic switch, inductor or capacitor is assembled in a separate small and individual base, and its place is left empty (with connectors only) in the module frame. That separate base is made of fiber board and has the power, i.e., high current connections at the bottom side, and the gating pins if exist are accessible at the top side through molex type connectors. The solution of using detachable devices in the power circuit facilitates the substitution during the classes and provides the student contact with the devices. The power module also has integrated shunt resistors for measuring currents and visualizing waveforms.

2) Mechanical Assembly

A standard platform was adopted for assembling the modules, composed by a wood box made of 15mm thick pine wood board. The coating material used was the light yellow colored and textured Formica[1], applied at the sides and at the bottom side of the box. The approximate box dimensions are 310mm x 226mm x 70mm. The boxes were built in the school's own carpentry. A layer of immunizing product was applied to protect the wood against insects. In the top side of the box, a 8,0mm lowered frame allows the fit in of the wood module's panel, which is 3mm thick and has one side (top) white colored. It is A4 sized, such that the panel's layout can be printed in a inexpensive and common inkjet printer without the need of cutting the layout. Acetate transparency was chosen as layout's substrate. After printing, the re should be applied a layer of varnish in the printed side to protect it against humidity, because the ink is water based (a laser print would not have this problem). The covering of the panel is a 2,0mm tick, transparent PET[2] plastic sheet. This kind of plastic is similar to acrylic but is easier to drill, cut and mill, because it does not fracture as easier as the former one does. The module's panel is therefore assembled like a sandwich of three layers: wood + transparency + PET, owing good mechanical resistance and aspect. In the panels layout the drilling centers and connections are left marked, so that all the three layers in the sandwich can be drilled simultaneously without mismatches. A photo of the standard module box is shown in Figure 1.

Figure 1 – Box border photo showing the height lowering, the white panel base, and the PET panel covering. The Formica covering of the sides can also be seen.

3) Developed Kits

The first developed kit was the line commutated controlled rectifiers kit, composed by three modules: monophase command module, threephase command module and power module.

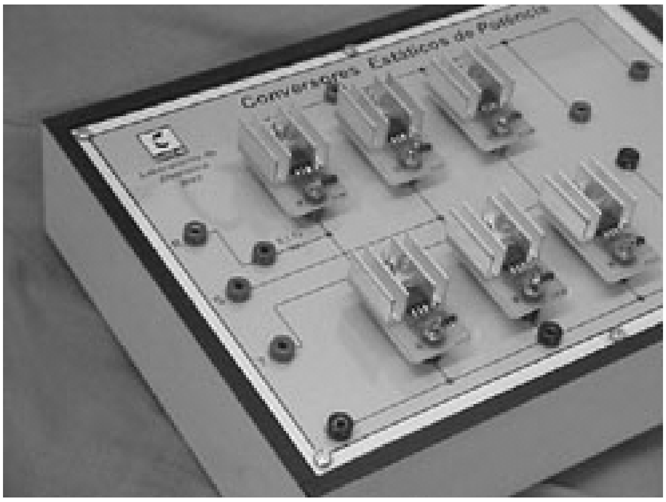

Figure 2 – Power module for assembling several static power converters (Graetz Bridge). The devices are all detachable.

The power module was built in a way such that it allows the implementation of several kinds of rectifiers in the same base. In fact, it is the threephase bridge (Graetz bridge), with the switch places left empty (with connectors only). In the place of a switch one can insert a SCR or a diode, what allows the composition of the following circuits: Non controlled monophase or threephase, half wave or full wave rectifiers; and fully or semi-controlled, monophase or threephase, half wave or full wave rectifiers, all of them with or without freewheeling diode. It can also be used as power

[1] A hard to risk, heat and humidity resistant thin laminated material.
[2] PolyEthylene Terephthalat

module of monophase and threephase transistor inverters. Its photo is shown in Figure 2, where it can be seen with the power devices in place. The power device can be seen with more details in Figure 3.

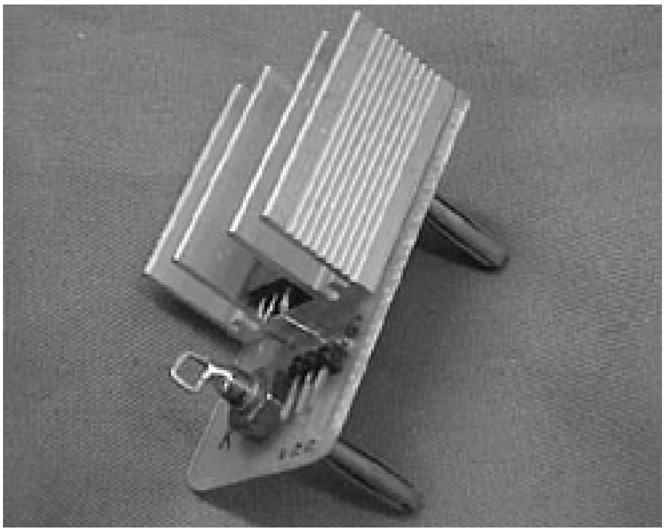

Figure 3 – Power device (thyristor) assembled on its base. The small heatsink can be seen as well as the power pins and the gating connector. The ring soldered on the cathode power pin facilitates the scope probe connection.

The command modules integrate the switch gating circuits and have electrical isolation in the synchronism stage, power supply stage and in the output pulse stage. The trigger angle is determined by voltage level (0–10V) and can be manual, through a potentiometer, or remote, through a PLC or microcomputer, thus closing a control loop. A photo of the threephase command module is shown in Figure 4 and in more details in Figure 5.

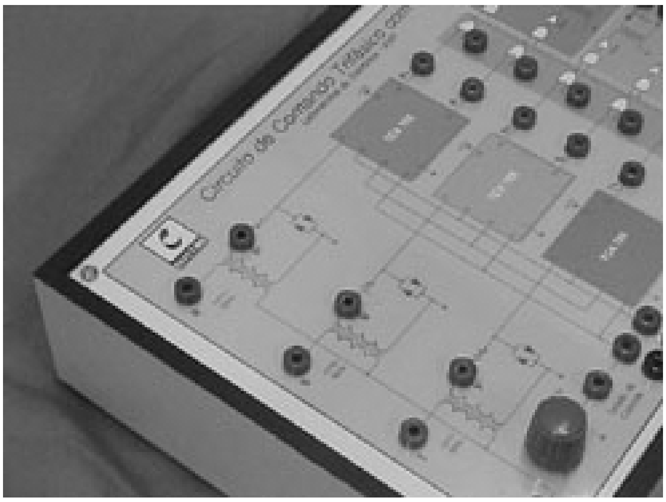

Figure 4 – Threephase command module

To serve as loads to the rectifiers (and also to other converters such as choppers for example), DC motor-generator sets were built, as shown in Figure 6. The machines, which are rated at 3/4HP (90V@9A), were assembled over ordinary scholar desks with wheels to facilitate transportation.

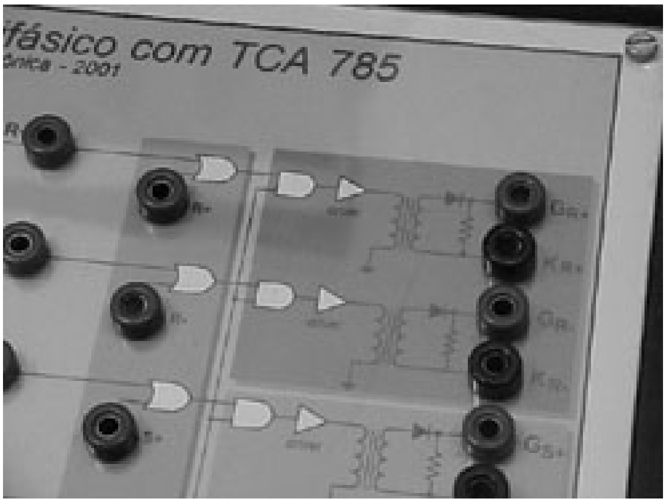

Figure 5 – Threephase command module detail

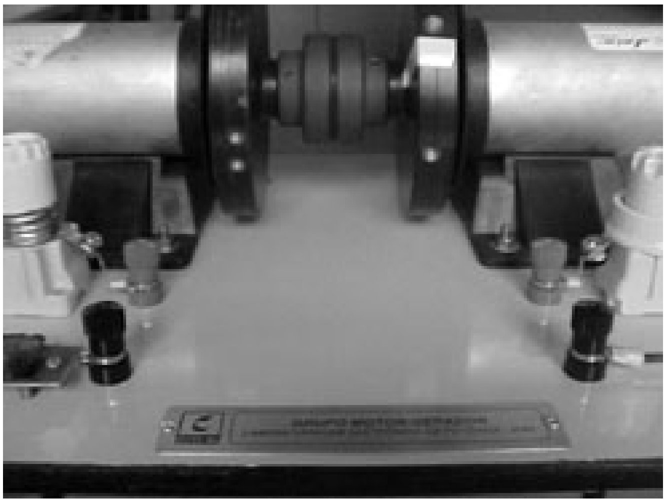

Figure 6 – DC Motor Generator set.

Figure 7 shows the experimental results of the threephase halfwave controled rectifier driving a DC motor. The source of the gating pulses is the module of Figure 4.

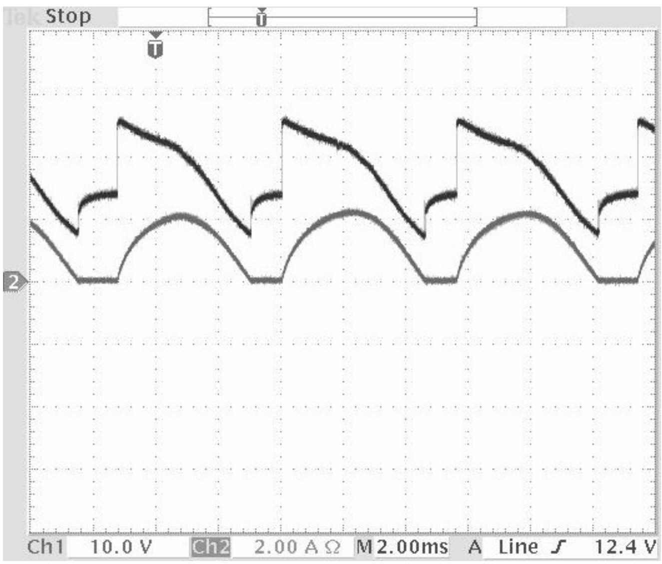

Figure **7 –** Experimental results of the threephase halfwave controled rectifier driving a DC motor. CH1: Output voltage. CH2: Output current.

3) Further Developments

Other kits are in advanced phase of development, such as the PWM command module for choppers, switch mode power supplies and inverters. In this kit, the switch gating modules will be placed in separate small plastic boxes because the need of being close to the gate of the MOS switches. The box is 14cm x 11cm x 4cm sized.

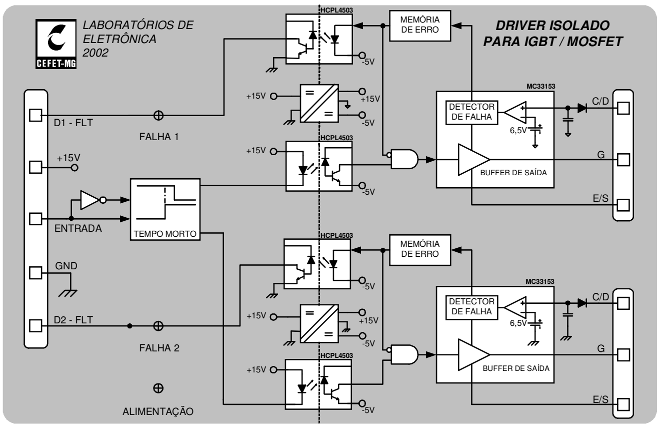

Figure 8 – Panel of the inverter leg gate drive module.

Moreover, each one of those small gating modules will allow to drive an inverter leg and will have built in electrical isolation, switch overcurrent protection and the dead time circuit. Its planned panel is showed in Figure 8. That gating module will allow not only the realization of common classes in the laboratory but also will facilitate implementation of converters in the research tasks.

The PCB of the PWM command module is ready and the command waveforms for sinusoidal modulation are shown in Figure 9.

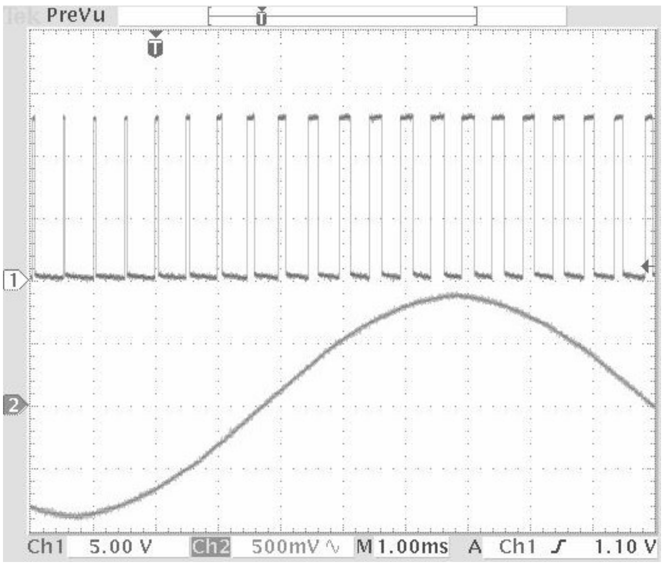

Figure 9 – PWM command waveforms. CH1 PWM command signal and CH2: modulating signal.

Another module that is being planed is the threephase command module for transistor inverters. It will use the Texas MSP430 mixed signal microcontroller, and will allow implementation and testing of converters control strategies.

III. CONCLUSIONS

After more than three semesters of use, the assembled kits have proved to be robust, with little need for maintenance. The classes became more advantageous and interesting, and a new working dynamic has been established. The kits allowed the classes to go beyond what had been traditionally realized in the laboratory. The experiences acquired and the good results obtained with the first kits induced the team to start developing new ones. It is important to remember that the construction of the kits has been done with human resources and material of the own school, with direct participation of the teachers not only in the conception phase but also in the construction phase too.

ACKNOWLEDGEMENTS

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