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FPGA Implementation of Frequency Dividers in Vocational Education

Ionel Bostan
Department of Electronics and Computer Science
University of Piteşti
Piteşti, Romania
ionel.bostan@upit.ro, robert.beloiu@upit.ro,

Guillermo Ferrando, Carlos Hoyos
Department of Electricity and Automation
XABEC Professional Training Center
Valencia, Spain
guillermo.ferrando@xabec.es

Abstract* – This paper present a group of practical activities which was designed to improve practical activities in teaching frequency dividers in VET using a tool named *ProjectX.

Keywords: FPGA, frequency dividers, vocational education, mobility, ProjectX.

I. Introduction

A long period of time general and higher education played a major role in the European education and vocational education and training (VET) only a minor role – the thinking being that it offered less good job and even less promotion opportunities.

In order to support and improve the quality of the VET a series of European instruments was developed since 2002, from Copenhagen Declaration: European Qualifications Framework (EQF); European Credit system for Vocational Education and Training (ECVET); European Qualifications Framework (EQF); Europass framework. All these instruments provide the legal framework for: strengthening of the European dimension in VET; cooperation in the field of quality assurance; recognition of competences and qualifications; transparency information and counselling; mobility and lifelong learning. All these instruments try to make VET "more attractive".

The growing importance of VET it is recognized in various documents elaborated by European Centre for the Development of Vocational Training. For example, in a research report in 2011 shows that "VET will continue to play an important role in the shift towards more knowledge-intensive societies" and "nearly half of the jobs in 2020 will require a medium-level qualification, which will often be achieved by some form of VET" [1].

In present, after economic crises, European VET systems must find solutions for a new series of problems: the large number of young people with low qualifications or no qualifications at all; technological change will increase the demand for people with medium or high qualifications; the mobility of learners in VET remains low; curriculum does not keep pace with rapid technological change; reduced investment in VET due to economic crisis. In order to increase the flexibility, the quality and efficiency and attractiveness of VET, the Bruges Communiqué establish eleven strategic objectives for the period 2011-2020 and a set of short-term deliverables for period 2011-2014. Among them, from this paper point of view, most important are those: "encourage practical activities and the provision of high-quality information and guidance"; "give learners in I-VET access to appropriate up-to-date to technical equipment, teaching materials and infrastructures"; "the mobility of workers and learners"; "promote active learning" and "ensure access on an equal basis" [2].

In this context the project "*one2one - One Teacher and One Students working with ProjectX* ", developed under European Longlife Learning Programme, aims to develop practical activities that can be done in any VET school, using a tool that was called *ProjectX*. In the *one2one* framework, seven schools from different European countries, have worked together to achieve a twenty one *ProjectX* portfolio, covering different arias of studies, as an initial collection of practical activities which can be chosen by any student from any European vocational school [5]. Each *ProjectX* was developed on the basis of Learning Outcomes and ECVET credit system in order to increase the mobility of students and teachers between different institutions. One aim of *one2one* was to offer a tool (which is *ProjectX*) and a collection of implementation examples (twenty one tested and fine tuned *ProjectX* applications) as a basis for a further development [4] [6].

One of the twenty one *ProjectX* which are already completed has the objectives to study counters and frequency dividers and implement these circuits using general purpose logic integrated circuit or reconfigurable logic circuit such as FPGA. Parts of this *ProjectX* are presented in various levels of detail in this paper.

II. Project description

A. General structure of the ProjectX

In the meaning of *one2one*, a *ProjectX* is "a methodological guide for the student to carry out a concrete activity, one to one with a teacher, in which theory and practice are both perfectly integrated and is related to the real workplace [3].

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Promoting school of each *ProjectX* should define very clearly the following aspects: ECVET level of the project; Learning Outcomes that will be achieved; time budget of the project; objectives of the theoretical part and practical part; all the tasks to be performed by students; student guide; teacher guide; all bibliographical materials needed to fulfill the projects. At the end, each *ProjectX* will be evaluated and implemented by other partners, in order to improve the quality and transferability of the project.

B. Applayed ProjectX in Teaching Frequency Dividers

ProjectX with name "Implementation of digital frequency dividers" is an advanced project in digital electronics, specifically in the area of sequential logic circuits. This topic was selected for two main reasons: (1) to cover the area of sequential logic circuits which are more difficult to understand by students; (2) counters and frequency dividers are basic blocks in almost any modern digital equipment, from traffic lights to computers.

After an initial theoretical documentation regarding flip-flops, counters and frequency dividers implementation techniques, each student are going to perform three groups of practical activities:

- simulate different counters and frequency divider using dedicated software programs;
- implement and test different counters and frequency divider, on breadboard, using general purpose logic integrated circuits; and
- implement and test different counters and frequency divider using modern digital circuits such as FPGA.

In the first group of practical activities, students must accomplish a number of simulations that gradually increase in complexity. A complete list of suggested simulations is presented below:

- 4-bit asynchronous counter implemented with JK Flip-Flops;
- frequency divider with division factor *K=10,* using 4-bit asynchronous counter implemented with JK Flip-Flops;
- frequency divider with *K=6,* using 4-bit asynchronous counter implemented with JK Flip-Flops;
- frequency divider with *K=10,* implemented with 7493;
- frequency divider with *K=6,* implemented with 7493;
- frequency divider with *K=60,* implemented with 7493;
- countdown 4-bit synchronous counter implemented with 74193;
- programmable frequency divider implemented with 74193;
- programmable frequency divider with programmable duty-cycle implemented with 74193;

For each simulation students must follow a series of steps as: draw the diagram; choose the appropriate type of analysis; display electrical signals in different points of electrical diagram; learn how to use virtual instruments (incorporated in software tools).

In the second stage, some circuits that were simulated previously are going to implement on prototype board (breadboard), using general purpose logic IC, A complete list of required practical experiments is presented below:

- 4-bit asynchronous counter implemented with 7473;
- frequency divider with *K=10,* implemented with 7473
- frequency divider with *K=10,* implemented with 7493;
- frequency divider with *K=60,* implemented with two 7493;
- programmable frequency divider with programmable duty-cycle implemented with 74192;

For each experiment student must follow four steps:

- convert *logic diagram* into *wiring diagram* (use data sheet; make right allocation of internal resources of the IC to cover all components of the logic diagram; decide what to do with unused resources and/or unused IC pins; make connection between pins; specify pins for power supply; specify the number of pin and the number of IC for each logic symbol);
- breadboard implementation of the electrical diagrams (place all components; make wired connection between components, according with electrical diagram; make final verification);
- prepare to test the circuit (make ground connections between power supply, signal generator, breadboard and oscilloscope; connect signal generator to the breadboard; set the correct voltage on power supply and make connections to the breadboard);
- testing the circuit (power on signal generator, oscilloscope and power supply; connect one channel of the oscilloscope to the input of the divider and the second channel at the output of the divider; set desired frequency for clock signal; use oscilloscope to display and to determine the frequency of the input/output electrical signals);

As an example, in Figure 1 is presented the electrical diagram designed by students in order to simulate a programmable frequency divider with programmable duty-cycle.

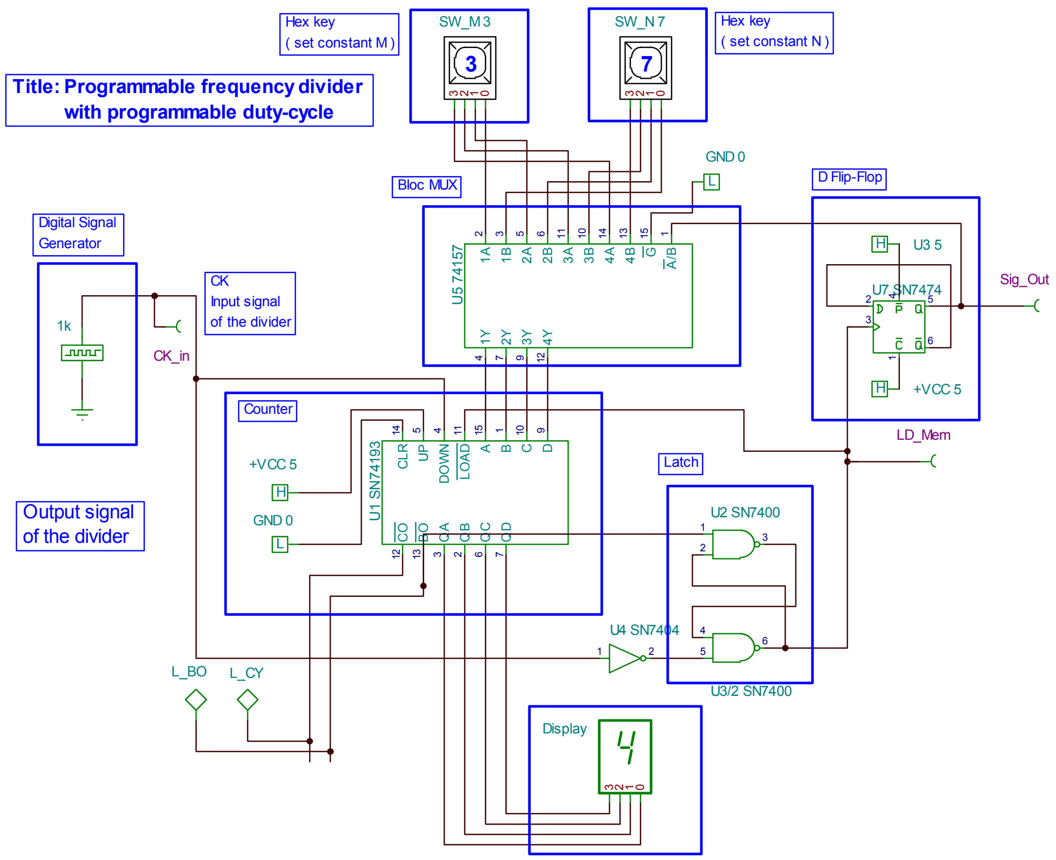

Figure 1: Electrical diagram used to simulated a programmable frequency divider, using general purpose logic IC

The last group of practical applications is the most attractive for students because they design a hardware product in a manner that is very similar to make a software program. This group of practical activities is presented in more detail in the next section of this paper; the first two were presented in detail in Procedia - Social and Behavioral Sciences [4].

III. USING FPGA IN LEARNING FREQUENCY DIVIDERS

Working with FPGA is not an easy task but is the most attractive and flexible modality of implement modern digital circuits. Generally speaking, for each FPGA application it is mandatory to make a project in which to specify the target circuit, its logic function and how external devices are connected to the FPGA.

To make things easier, all applications will start from a *Project_Template* in which the student will place their application in well delimited area. In this template there are already implemented some useful tools in order to access the resources of the board or in order to see the state of the counter: (1) a programmable signal generator; (2) one BCD to 7segment decoder in order to display the state of the counter in decimal format, and (3) one driver in order to display the state of the counter in binary format on *Basys 2* LED's.

All experiments will be implemented in *ISE Project Navigator* software and will be tested on *Basys2* board. A complete list of required projects to be implemented in FPGA is presented below:

- getting starting with *Project_Template*;
- use *Project_Template* to implement 4-Bit asynchronous counter using FJKC components (generic JK Flip-Flop from ISE Library);
- use *Project_Template* to implement frequency divider with *K=10,* using FJKC components, as shown in Figure 2;

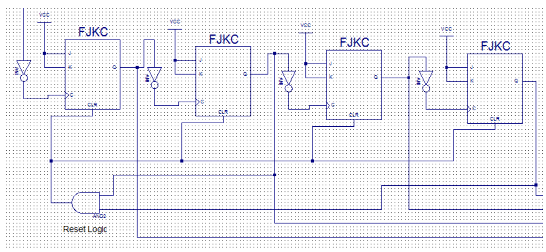

Figure 2: Logic diagram of a frequency divider with K=10

- use *Project_Template* to implement frequency divider with *K=10,* using CB4CE component (generic 4-Bit asynchronous counter from ISE Library), as shown in Figure 3;
- modify last two projects to obtain divider with *K=5*;
- use *Project_Template* to implement programmable frequency using CB4CLED (4-Bit synchronous, bidirectional, presetable counter from ISE Library), as shown in Figure 4;

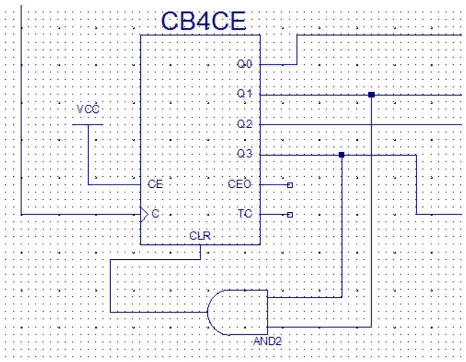

Figure 3: FPGA implementation of a frequency divider with K=10, using a generic counter named CB4CE

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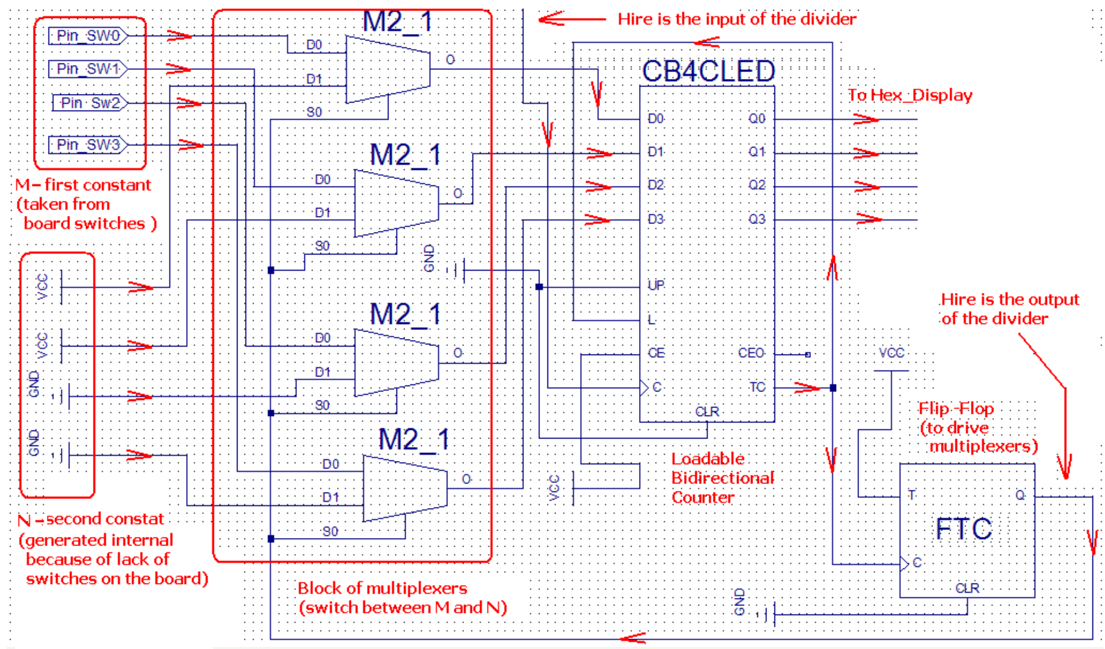

Figure 4: FPGA implementation of the divider presented in Figure 1, using a generic counter named CB4CLED

For each experiment students must follow a series of steps: load *Project_Template*; modify the working area according with logic diagram; update the constrain file; generating programming file; download the programming file using *Digilent Adept* communication tool; test the functionality of the implemented circuit. In case of malfunction it will be necessary to make changes in schematic, remake programming file, download the new configuration bitstream into FPGA and test again.

IV. CONCLUSION

Students who tested this *ProjectX*, at the end of all practical activities were able to simulate, design and implement counters and frequency dividers or other logic circuits with same complexity level. They learn to implement and test logic circuits in two different technologies: (1) using general purpose logic IC; (2) using most recently logic IC such as FPGA. A good understanding of these circuits and ability to work with FPGA as well as working with general purpose logic IC are essential skills for a well-trained technician in electronic field.

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