An SDRAM test education package that embeds the factory equipment into the e-learning server

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Abstract - **SDRAM (Synchronous Dynamic Random Access Memory) demand has grown exponentially since the 1980s, as a result of technological factors and new areas of application, particularly concerning communication and consumer electronics. The SDRAM market represented in 2007 c. 20% of the total semiconductor business and is seen as a strategic area, justifying private and public investment in the western and far-eastern economic communities. SDRAM test education is therefore an important subject, but very high purchase and maintenance costs keep test equipment beyond reach of most university test courses. This paper presents a pilot project addressing an SDRAM test education course developed jointly by Qimonda and the University of Porto (FEUP), where the company offers remote access to one if its Advantest SDRAM automatic test equipments. Access to this remote tester was embedded into the Moodle e-learning server that supports a new course entitled Electronic Systems Testing (TSEL), which is part of the Integrated Masters degree on Electrical and Computer Engineering at FEUP. The excellent feedback received from students encouraged us to extend this cooperation into an educational network, which is also introduced in this paper.**

Index terms – **SDRAM test equipment, remote experimentation, e-learning.**

I. INTRODUCTION

A. *Problem definition*

SDRAM production is a capital intensive business and in an Assembly&Test plant, such as the one in Portugal, the cost of test equipment is close to 50% of the plant investment. An automatic tester for high-volume SDRAM production tests may cost in excess of 5 M€, not to speak of operational and maintenance costs. For these reasons, university courses that address SDRAM testing concentrate on pattern generation algorithms and other theoretical aspects, leaving much to learn with respect to test development skills and real manufacturing test practices. This problem was recognised by Qimonda Portugal, which consumes up to 6 months for training newly hired engineers in this field.

B. *Novelty*

Since the engineering and production testers are all connected to the company's network, it became common practice to share the sophisticated test equipment among the Qimonda Product Engineering & Test locations around the world in USA, Germany, China and Portugal, in this last case sharing facilities with a production plant, where the production test programs for the full spectrum of Qimonda memory products come from.

The idea of enabling remote access to a tester located in company's shop floor came naturally as an extension of the routine work carried out at the Qimonda's plant in the vicinity of Porto. A pilot project to evaluate the learning effectiveness of this approach was set up and described in [1]. The novelty of this paper consists of presenting the results of that pilot project, and of proposing an educational consortium based on the results and experience accumulated during the Electronic Systems Testing (TSEL) course that was offered for the first time on the 2007 / 08 edition of the Integrated Masters degree on Electrical and Computer Engineering.

C. *Organisation*

The next section debates SDRAM test education and remote engineering practices, and introduces the on-line workbench solutions developed within FEUP's Labs-on-the-web project. Section 3 describes the remote Advantest station available at Qimonda's premises in the vicinity of Porto, and explains how the students carry out test assignments. Section 4 presents the learning model of the TSEL course module. The very positive results achieved during the first edition of this course, in the current school year of 2007/08, encouraged Qimonda and FEUP to plan an SDRAM test education network, which is introduced in section 5. Finally, a concluding section summarises the work done and the results achieved.

II. SDRAM TEST EDUCATION AND THE LABS-ON-THE-WEB PROJECT

A typical SDRAM test course will combine architectural concepts, fault models, pattern generation algorithms, and eventually one or more chapters dedicated to automatic test equipment [2,3]. Various universities offer courses in this area and there is a wide variety of learning materials in printed and e-forms. Most of those courses, however, will exclude hands-on sessions with real production test equipment. An automatic test station for today's SDRAM devices, such as the one illustrated in figure 1, can easily cost a few million euros, and requires a controlled environment, software licences and an expensive maintenance program.

On the other hand, the university campus is hardly the appropriate space for an SDRAM production tester, which would be largely out of context and very sporadically used. However, without access to real test equipment, the students will hardly acquire any practical test development skills. As a result, those that come to work in this area will have to go through an extensive training program, which in the case of Qimonda Portugal might reach up to half-a-year. In-house, the engineers establish remote access to the engineering and production test equipment – test development and product analysis is done from the engineering offices, but the testers are located in the factory floor. Technically speaking, there is no difficulty to access an automatic test station remotely. The trend to offer remote access to laboratory workbenches is wide-spreading rapidly in universities worldwide, and many research projects have addressed the development of *remote labs* and *virtual labs* in the last decade[1].

Figure 1: A typical automatic production test station for modern SDRAM devices.

When Qimonda considered the possibility of offering remote access to an automatic SDRAM test station, the University of Porto (FEUP) had just launched a project entitled Labs-on-the-web, with financial support from the POCI 2010 programme (Programa Operacional Ciência e Inovação).

The main objective of the Labs-on-the-web project, which runs from November 2006 to June 2008, consists of evaluating the pedagogical effectiveness of providing web access to laboratory workbenches in engineering degrees [4:7]. The Labs-on-the-web consortium comprises the Engineering and the Educational Sciences schools of the University of Porto, which are responsible for the technical and pedagogical assessment tasks in the project workplan. Remote access to Qimonda's test equipment and the Labs-on-the-web project provided a perfect match, particularly because this opportunity offered a rather uncommon case study: instead of accessing a lab at the campus from home, the students are now located at the university campus and access an "SDRAM test workbench" located in the company premises.

III. QIMONDA'S REMOTE ADVANTEST STATION

Following an exploratory contact held in early 2007, Qimonda decided to provide remote access to a T5365 SDRAM automatic test station located in the company's premises at Vila do Conde, in the vicinity of Porto.

Tester set up is illustrated in figure 2 and was concluded during the summer, being available for the students by September 2007.

Figure 2: T5365 installation and set up at Qimonda.

This tester enables parametric and functional testing of lower-speed SDRAM components and supports remote access via a dedicated ADSL line. For security reasons, it is completely isolated from the company's LAN. To prevent misuse, access is granted only to FEUP's IP addresses (the students may still access the tester from their homes, if connected to FEUP via VPN).

The test assignment workflow starts by an off-line phase dedicated to test program development, using Notepad++ or any other text editor, as illustrated in figure 3.

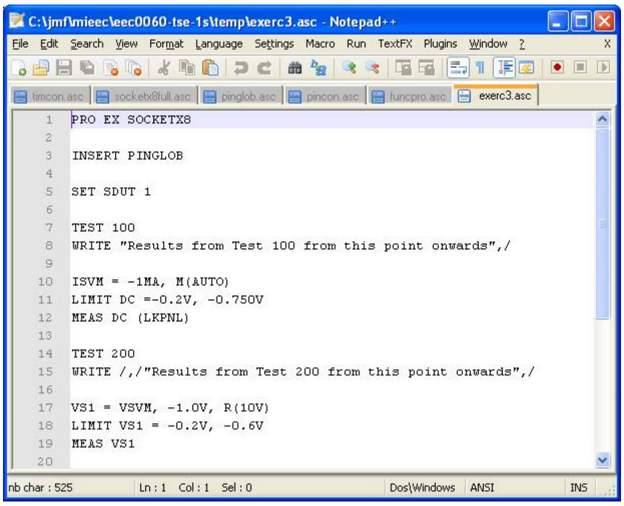

Figure 3: Editing the test program source code in Notepad++ (off-line).

Once the test program is ready, the student will log into the remote tester workstation and transfer the source code using a secure shell transfer client application, as illustrated in figure 4.

Since the remote tester only grants access to known IPs, the student should be at the university campus or connected to the university network via VPN.

[1] A *remote lab* offers access to physical equipment that is normally located in the university campus, while a *virtual lab* deals with simulation models.

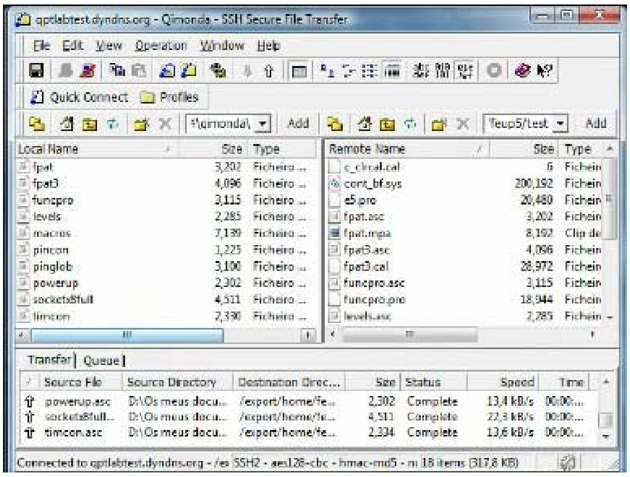

Figure 4: Transferring the source code to the remote tester via SSH (on-line).

Test program compilation can then take place ("trans" command), as shown in figure 5. Since the test compiler is a multi-user package, several students may be logged in and compile their programs at the same time.

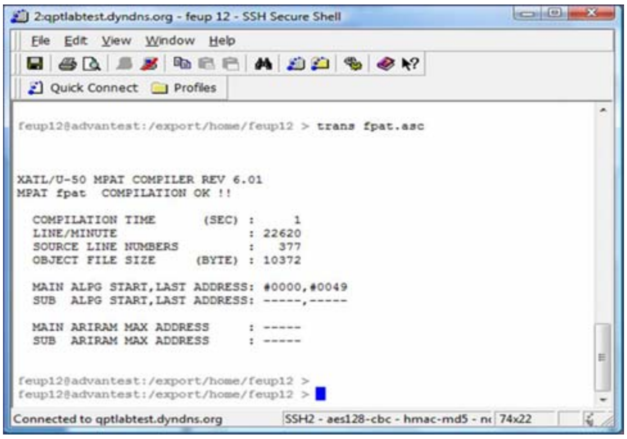

Figure 5: Compiling the source code (on-line).

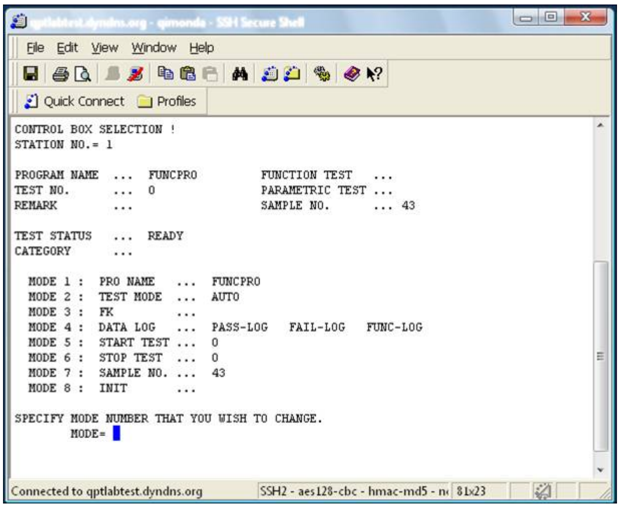

Figure 6: Control box configuration (on-line).

Following successful compilation, the student is ready to access the tester and check if the device placed in the tester responds correctly ("test" command). Since the test head is a single-user resource, only one student at a time can test the device. Test execution via SSH proceeds as shown in figures 6 and 7, which illustrate the control box configuration and test results.

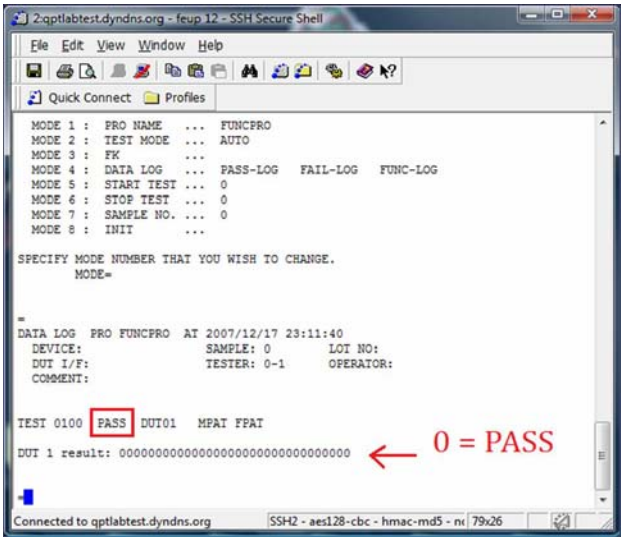

Figure 7: Test results (on-line).

The remote tester was used to support practical test assignments within the scope of a new course module entitled Electronic Systems Testing (code name TSEL), which belongs to the final year of the Integrated Masters in Electrical and Computer Engineering. TSEL addresses electronic testing activities, with an emphasis on SDRAM testing.

Since all course contents are available via Moodle, the e-learning platform was also used for scheduling access time and to validate access rights by interaction with the remote tester workstation.

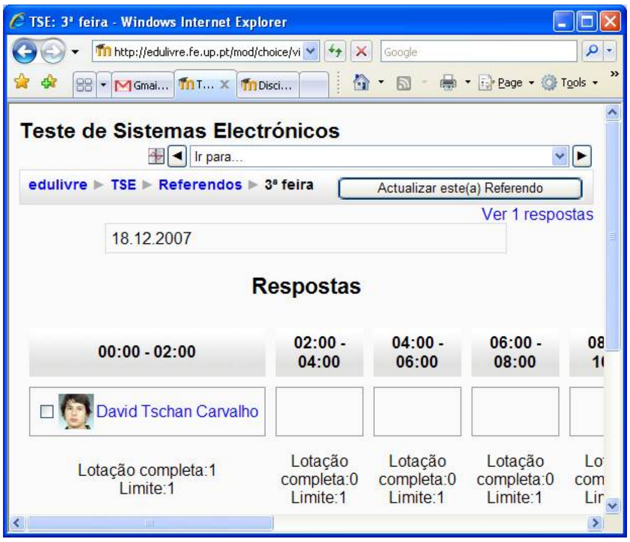

Figure 8: Scheduling access time to the remote tester via Moodle.

Scheduling is possible through a Moodle activity called “Survey”, which enables the students to select one item from a list of alternatives. For scheduling purposes, the list comprises 2-hour periods that correspond to the remote tester access slots. Besides the standard “survey” activity, a Moodle PHP scheduling script was developed that returns the username of the student that booked the current time slot (or ‘blank’ if no one booked the current slot, in which case the log in request is also accepted). As soon as each student indicates his / her preference, that time slot is blocked and associated to that student, as shown in figure 8. The remote tester inquires the scheduling script whenever a student tries to log in, and checks if the username obtained in response matches the username of the student that is trying to log in. If the two usernames are different, log in is refused.

The interaction between the remote workstation and the Moodle server explains why the students perceive the tester as an embedded e-learning resource.

IV. LEARNING MODEL OF TSEL 07/08

Offering a course in cooperation with Qimonda was also an opportunity to propose a learning model closer to the industry training needs and in full compliance with the goals and action lines of the Bologna process. First and foremost, theoretical lectures and written exams continue to exist, but play a much less important role in the course workplan, which relies heavily on teamwork and task assignments. A brief description of the learning model adopted for TSEL 07/08 is presented in the following sections.

A. Workplan

The workplan for TSEL 07/08 comprised two parts: i) An introductory part that offered an overview of the semiconductor and memory markets and the acquisition of essential skills in the engineering area; and ii) a second part entirely devoted to task assignments.

Part 1 lasted for 4 weeks and included guest lectures addressing semiconductor production and DRAM technology. This part also included a workshop on leadership and teamwork, which represent important skills for part 2, where all tasks are carried out as teamwork. Part 1 closes with a visit to Qimonda’s plant in the vicinity of Porto, where the students have the opportunity to accompany the various steps and processes involved in SDRAM production. At this plant, Qimonda produces c. 5% of all SDRAM production worldwide and offers an excellent example of all assembly and test operations involved in semiconductor manufacturing.

Part 2 comprised a set of 2-week assignments where the students prepare a presentation on the proposed topics. Due to its importance in the course plan and in the final classification achieved by each student, a detailed description of the assignments model will now follow.

B. Assignments

Every assignment comprises a set of topics proposed for teamwork, and delivers a presentation at the end of 2 weeks. The topics proposed may or may not be different for the various groups. The main rules governing the assignments model are the following:

- A group comprises 4 students +/- 1 (an appropriate dimension for 2-week tasks and to enable task sharing between all team members)
- Group composition changes for every assignment (to promote collaboration skills and quick adaptation to new colleagues, independently of personal preferences)
- A team leader is appointed by the teacher for each new group (all students play the role of team leader)
- The outcome of each assignment is a 30-minute presentation made by one of the team members, appointed 48 hours before the session (all students play the role of presenter, but are informed only at short notice)
- All students in the same group receive the same classification (being aware of this rule, the students will react against unproductive attitudes or misdistribution of the workload)

Assignments contribute to up to 75% of the final classification achieved by each student, as described in the following section.

C. Assessment model

The learning model used in TSEL was adapted from a course on Logistics offered at FEUP [8], and combines a written exam (25%), a cross-assessment component carried out by the students (25%), and the classification obtained in the complete set of assignments (50% in total). Since the duration of the semester enables 4 to 5 assignments, their individual weight will vary between 10 and 12,5%. The classification per assignment is common to all students in the same group, but the two other assessment components correspond to a personal classification and are therefore used to reward the best students.

The cross-assessment component is carried out by the students at the end of the semester. Each student fills in a form containing a matrix-like structure that compares every pair of students (A,B) that he / she worked with in any assignment, either as team member or group leader. This comparison simply indicates if A was better, equal, or worse than B. A set of Excel macros read the student forms and builds an ordered list based on all the comparisons made. Notice that this component provides personal information for each student, which is far more reliable than what a teacher might be able to achieve, since it is not possible to fully accompany the activity carried out by a group of students. This component outweighs the light injustice that results from awarding the same classification to all the students that belong to the same group.

Positive discrimination is also achieved by an individual written exam, where the students are assessed concerning the theoretical concepts underlying the practical tasks that were implied by each assignment.

V. PROPOSAL: AN EDUCATIONAL SDRAM TEST EDUCATION NETWORK

Following the very positive feedback obtained from the students in the first semester edition of TSEL 07/08, Qimonda and FEUP are planning to create an interest group in this area. In its current preliminary form, this network may be presented as follows:

- Objective: To achieve excellence in SDRAM manufacturing and test education
- Resources: The T5365 remote tester available at Qimonda's premises in Porto and a standard e-learning package for Moodle
- Cooperation framework: The European Education and Training funding programmes, namely those that are part of the Lifelong Learning Programme and the ALFA programme

Further information with this respect will probably be available during the conference.

VI. CONCLUSION

This paper presented the results of a pilot project addressing SDRAM test education, where Qimonda and the University of Porto (FEUP) developed an innovative e-learning package that integrates a T5365 Advantest station into a Moodle e-learning server. The automatic test equipment is located in the company's premises and offers remote access to teams of students that carry out parametric and functional test assignments. This package supported a new course module entitled Electronic Systems Testing, which is part of the Integrated Masters in Electrical and Computer Engineering at FEUP. The pedagogical effectiveness of this approach was evaluated within the Labs-on-the-web project led by FEUP with support from the POCI 2010 programme, and the technical expertise at Qimonda was ensured by the Product and Test section. This test development team currently with more than 30 engineers is located at the production facilities in the vicinity of Porto.

The excellent feedback obtained from the students proved that SDRAM test education is greatly improved by offering remote access to real test equipment that can only exist in a memory manufacturer shop floor. University-industry cooperation in this area also enabled additional benefits, namely by offering the students a closer look at real-life work environments, and by promoting team work and cross-assessment responsibility, which are fundamental values in the engineering profession.

The successful outcome of this pilot project encouraged Qimonda and FEUP to propose an educational network on SDRAM test education, which is currently in its launching phase.

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