Texas Instruments & Texas A&M Validation Course Collaboration

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Abstract

With the ever-changing world of industry, it remains imperative that academic curricula keep pace to provide the education needed for students to be successful upon graduation. A long-standing relationship between Texas A&M University and Texas Instruments (TI) exemplifies the collaboration needed to maintain state of the art curricula. Semiconductor validation is one of the early steps in the product quality assurance process, and as such is a critical part in semiconductor new product development. Validation engineers must perform high end product performance analysis, primarily utilizing tools such as those developed by National Instruments, LabVIEW, and Test Stand. Although LabVIEW is taught at the rudimentary level at most major universities, a novel focused course on semiconductor validation was needed. A team consisting of six validation engineers from TI with two faculty and six students from Texas A&M University developed such a course during the summer of 2016. To expose students to industry topics, TI engineers gave approximately six guest lectures for each course offering to date at Texas A&M University. To expand the impact in academia, in 2018 the validation course was replicated at the University of Puerto Rico at Mayaguez by two faculty members and two graduate students and is currently offered as an engineering elective course. The validation course will be presented as well as results from the first four course offerings (2016 to 2019) at Texas A&M University.

1. Introduction: Need for Action

The motivation to create a validation course was in part to develop a strong validation talent pipeline and also to enhance the relationship between TI and the Texas A&M Electronic Systems Engineering Technology (ESET) Department. A trend in the semiconductor industry to formalize the post-silicon validation role began around 2010. This trend led to a need for more highly trained validation talent, and in 2016 an opportunity arose to collaborate between Texas A&M and Texas Instruments to fill this gap.

TI and Texas A&M began a mixed signal test curriculum in 1998 when TI supplied a Teradyne A567 tester. Two production focused mixed signal test classes (ESET 352 & 452) were taught from 1998 to 2017, and this curriculum utilized the mixed signal test book titled *An Introduction to Mixed-Signal IC Test & Measurement*, written by former TI Fellow Mark Burns and Professor Gordon Roberts of McGill University. To modernize the production test curriculum that once used the older Flex tester platform, TI supplied a new Teradyne Eagle ETS-364 tester (see Figure 1). TI Supplied Teradyne Eagle ETS-364 production tester) to the ESET Department in 2018.

The plan is to transition to the new Eagle test platform by updating the previous curriculum by 2020. The creation of the validation course followed a similar strategy to that of the development of the previous mixed signal test curriculum. As reference, this mixed signal test curriculum is now active at several specific universities (Texas A&M, Texas Tech University, University of Puerto Rico at Mayagüez).

Figure 1. TI-supplied Teradyne Eagle ETS-364 production tester

2. Actual Spark That Started the Relationship

What actually sparked the initiative to refresh the mixed signal curriculum and to include new validation curriculum at Texas A&M? It is consensus that this spark happened in 2015 when Texas A&M professors, Dr. Rainer Fink and Dr. Joe Morgan, and select ESET students presented their capstone projects at the TI Headquarters in Dallas, TX. The Texas A&M ESET department was presenting very engineering worthy concepts and ideals. First, the already established mixed signal curriculum was focused on hands-on lab and project-oriented learning. The senior design projects also followed a cross functional team model, and it was evident that they were being tasked with solving real world industry problems. And matched with the obvious interest and support from Dr. Rainer Fink to enhance the mixed signal curriculum, it was just the perfect moment to fold all of these attributes into an initiative to launch a new course (ESET 453) that would focus on semiconductor post-silicon validation.

3. Required Executive Level Relationship to Push the Mission Statement into Action

Successful long-term engagements between industry and academia are extremely difficult to build and maintain. Key individuals within each organization must maintain constant attention to

the interchange of information and resources. On the academic side, the university must have a dedicated champion who is interested and will take responsibility for maintaining relationships with industry as well as maintaining oversight of the quality of students graduating and eventually joining the industry member. Similarly, on the industry side, the corporation must have a dedicated individual to maintain oversight of funding and equipment issues as well as providing feedback on trends or shifts in industrial processes and needs.

To effectively execute the deployment of the validation course at Texas A&M, support from both TI executive and ESET Department leadership was required. In April 2019 the Texas A&M ESET Department and TI celebrated a 20-year anniversary of the relationship (see Figure 2). Also, support from TI's validation infrastructure partner National Instruments (NI) was significant in deploying the equipment used for the validation course. Both TI and NI agreed to supply PXI equipment for ten stations that would enhance the lab hardware experience of the class. TI Senior Vice President of Technology & Manufacturing Kyle Flessner stated, "This new Validation class is a great enhancement to the Mixed-Signal Test classes launched by retired TI Fellow Mark Burns years ago. You and the entire team should be commended for your above-and-beyond efforts to strengthen our collaboration with Texas A&M and build value into TI's talent pipeline going forward." This highlights the positive impact to Texas A&M and TI that has resulted from adding the new validation course into the ESET Department.

Figure 2. TI & ESET leadership celebrating 20 years of collaboration in mixed signal test

4. Initial Investment in Curriculum Generation

As with any productive long-term engagement, resources had to be dedicated to build the new course. As is often the case, industry has "best practices" that should be transferred to the faculty and subsequently the students. Although faculty are experts in the delivery of course materials, they are not necessarily experts in the new technology that is being developed. For optimal transfer of information and creation of course materials, faculty must be prepared to become embedded within the industry, allowing continuous opportunities to interact with experts in the

topic. In this case, Texas Instruments sponsored the professor, as well as four students, for the summer to engage with the development of the course materials. Course materials were developed in a sequential manner while focusing on the best practices used in the normal operations of a validation engineer. Furthermore, the direct contact between the industry experts and faculty allowed the identification of areas of expertise within TI that could be offered as guest lectures within the validation curriculum by TI employees.

5. Original Ideas and Reuse of Academic Fan Out of Curriculum

Texas Instruments has always needed a greater volume of qualified engineers than can be produced by any single university; thus they maintain many pipelines for talent acquisition. Streamlining the educational process in order to optimize the quality of graduates at a single university is only the first step in helping solve the talent issues. New engagements between universities have evolved in order to increase the number of potential new hires to industry. Sharing the course materials and best practices amongst several universities has significantly increased the impact of the original investment of the course creation and has helped to fill the talent pipeline with qualified validation engineers.

The validation course was originally launched in August 2016, and there was a huge demand initially for the course with 30 students registered and more than 20 waitlisted. The initial course development was very rigorous, with six TI validation leaders meeting with Dr. Rainer Fink weekly from February 2016 to September 2016 to generate the content for the course (initially 25 topics and 12 lab exercises). Also, four senior undergraduate students were selected to execute the labs over the summer to develop the practical solution files for the lab portion of the course (see Figure 3). There are typically six TI guest lectures selected and scheduled each semester as part of the course covering a range of topics on semiconductor validation such as: “IC Qualification & Reliability,” “Qualification & Validation of Space Grade IC’s,” “Data Analysis – Why and How We Use It in Industry,” “What is Validation and How Does it Ensure the Release of Quality Products,” “ Hardware Design and Layout Best Practices,” “IEC Testing,” “Electromagnetic Compatibility and Bulk Current Injection Testing.”

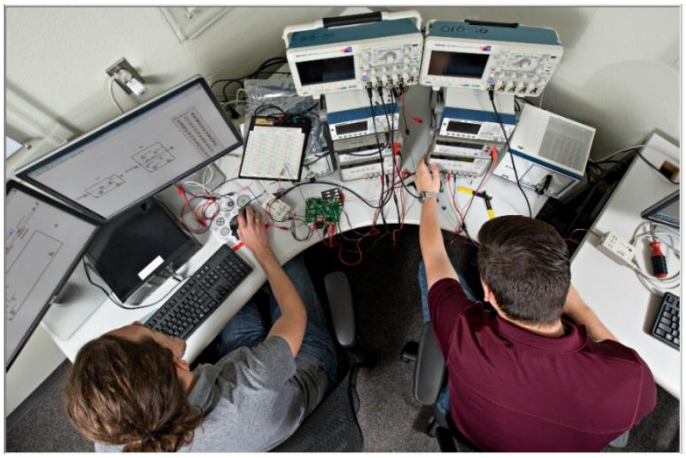

Figure 3. Two senior ESET students debugging validation lab at Texas A&M

The validation course has now been offered five times from 2016 to 2019 at Texas A&M. The course was such a success that it was adopted in August 2018 by Associate Professor Gladys Ducoudray & Professor Rogelio Palomera of the University of Puerto Rico at Mayagüez and has now been offered twice as a part of their electrical and computer engineering course work. Both TI & NI partnered again to supply PXI equipment to the University of Puerto Rico at Mayagüez in support of the classroom labs designed for the course. In 2017, the University of Puerto Rico at Mayagüez proudly celebrated their 20-year anniversary of the relationship with TI.

6. Original Accomplishments

The outcome of the newly revamped collaboration in 2016 between Texas Instruments and Texas A&M Engineering Technology and Industrial Distribution Department resulted in the first ever semiconductor validation course offered at Texas A&M (and possibly anywhere). The efforts of several students and faculty, in conjunction with TI employees, streamlined the course content into fifteen fully developed lectures and ten hands on lab exercises. All hardware required for the execution of the labs was acquired with support from TI and NI in time for the first day of classes. Guest speakers were scheduled, and lecture notes were prepared during the summer, so that the entire course was “ready to roll” at the conclusion of the summer. Intellectual property agreements were concluded for all lecture and lab materials such that no IP issues remained.

Figure 4, supplied by TI and NI, displays one of the original ten working validation instrument desktops designed and procured for Texas A&M through the engagement with NI and TI. The breadboard within this picture also identifies one of the two sets of device under test (DUT) semiconductor products featured in the curriculum. Each featured device is state of the art, and are products still actively shipping from TI. To support the expectations of a student learning environment, TI supplied 25 articles of each DUT type.

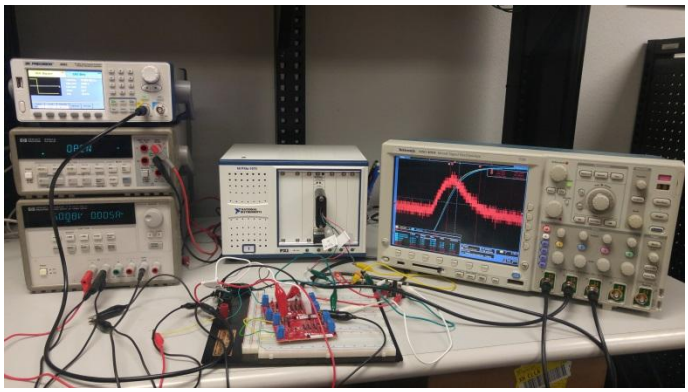

Figure 4. Example of instrumented test bench, supplied by TI and NI

7. What Has the Validation Curriculum Evolved into at Texas A&M

The semiconductor validation course material described in this paper was officially supplied to the faculty in 2016. During the first few semesters at Texas A&M, the lectures and labs were monitored and at times nearly taught by extension by the TI experts who worked on the

curriculum creation committee. To supply some independence from TI, Tom Munns (industry expert in semiconductor test) was hired as a senior lecturer in August of 2018 to teach both the lecture and labs of ESET 453- Validation. Since the official class rollout under the catalog name of ESET 453, Validation has been taught twice, Fall 2018 and Spring 2019 with a total of 45 students between those two semesters, and 19 in the current semester, Fall of 2019.

In academic terms, this class is taught as a "flipped lecture-classroom." That is, all formal lecture material is available to the student from the first day of class. Throughout the semester, the lecture material is meted out to the students as assigned reading by a scheduled date, and the class engages in a quick review and open discussion of any topic needing further explanation. Because this is a senior elective, the class is benefited by cross student conversation about some of these topics because many students have had their own experience in semiconductor validation or test from summer internships, or even prior employment. The current class teaching style is also experimenting with social and partnership relationships. The lab classroom is blessed with only nine "usually" working electronic instrument test benches, but on average twelve students per lab section, so students are required to work in teams. Faculty at Texas A&M find this situation understandable and attempt to use the situation to teach advanced teamwork and partnering skills.

Another policy that is also part of the overall architecture of the ESET 453 syllabus is that students are graded favorably for being the first team to accomplish the lab assignment. In fact, once approved, they are requested to help other teams with instrumentation and application questions about the lab. Within the department this is called the "flag" system, and the teacher will symbolically grant a team "green to go" status if they prove that they know what they are talking about. And once "green," they are deputized to be an extension of the lab teaching assistant or professor. Yet another aspect of the syllabus is that all of the lab assignments are required to be finished. Just like in industry, all tasks and jobs must be completed. The people who are promoted are typically the ones who always get those tasks done on time and on schedule. The last syllabus statement is that of inspiring extra credit for a "showoff" or research presentation. Basically, if within the semester a student or team discovers a better way to implement the lab, uncovers a new feature of the instruments or the silicon under test, that team is granted some extra credit points but is required to make a formal presentation of the new technology to the full class. In the past two semesters, the students who earn extra credit, who are confident in their discovery and in their written and oral presentation skills, are most often hired by TI or other companies within the semiconductor industry.

The curriculum of the Validation course is following a normal flow of evolution at Texas A&M, and one would expect at the other universities that received the content as well. Though all the technical content is relevant to the industry, some of the content could not fit within the bounds of a single semester (14-week schedule). The current list of lecture names and lab names are listed in Table 1. Many of the file names are self-descriptive, and can be used to monitor the included and excluded content shared originally from TI.

Table 1. Current list of file names issued to students at Texas A&M

Lecture names: ESET 453- Semiconductor Validation	Lab practical instruction names: ESET 453
A&M_ESET_Lecture1_Software_Part1.pptx	Gateway to Validation
A&M_ESET_Lecture2_Software_Part2.pptx	Lab 1 - Ron
A&M_ESET_Lecture3_Software_Part3.pptx	Lab 2 - AC Timing
A&M_ESET_Lecture4_Software_Part4.pptx	Lab 3 - Inrush Current
A&M_ESET_Lecture5_Hardware_Part1.pptx	Lab 4 - TestStand Orientation
A&M_ESET_Lecture6_Hardware_Part2.pptx	Lab 5 - BQ Orientation - IDDQ
A&M_ESET_Lecture7_Hardware_Part3.pptx	Lab 6 - VREG Parametric Tests
A&M_ESET_Lecture8_Val_Process.pptx	Lab 7 - OV_UV Tests
A&M_ESET_Lecture9_System_Functional_Tests.pptx	Lab 8 - ADC Parametrics
A&M_ESET_Lecture10_Break_the_Part_and_Thermal_Testing.pptx	
A&M_ESET_Lecture11_Planning_Part1_and_Part2.pptx	
A&M_ESET_Lecture12_Val_infrastructure_Flow_And_How_Val_Diff__Production_Test.pptx	
A&M_ESET_Lecture13_Printed_Circuit_Boards.pptx	
A&M_ESET_Lecture14_ADC_Validation.pptx	
A&M_ESET_Lecture15_ADC_INL and DNL.pptx	

8. Have There Been Bumps along the Way?

One major challenge facing academia is the rigidity of the standard curriculum. If a new course is developed, then something else must be left out or the course must fit into a technical elective slot, which reduces the number of students taking the course, and as such, the impact. In order to maintain the set credit hours required in the ESET degree, the second semiconductor test course (ESET 452) was removed and the course material was redistributed to several other courses. ESET 452 focused mainly on the testing of DACs and ADCs using multiple test platforms and evaluating the tester-to-tester correlation seen when a device is tested on two different test platforms.

Funding for course development, especially a course with laboratory equipment, is difficult to secure. Similarly, ongoing funding for continuous support for lab personnel (staff and student workers) is challenging, with a rigorous ROI expectation from industry. Student quality as well as volume expectations from industry must be clearly communicated so that all sides understand the limitations in the current and future graduating classes.

9. Results, Conclusions, and Future Efforts

As a result of the mixed signal test and validation collaboration at Texas A&M, TI has hired several engineers from the university between 2017 and 2019. To further expand the impact, there are plans to scale the validation course curriculum to a one weeklong lab intensive continuing education course titled “Bridge to Validation” and enhance the existing “Bridge to Test” continuing education course to utilize the new Eagle test platform. Also, there are plans to potentially leverage the skillsets learned by students in the undergraduate validation course as a prerequisite for students in the newly created master’s in Electronic Systems Engineering Technology to contribute to radiation hardness testing being performed at the cyclotron, located on the Texas A&M campus.

Biographical Information

MICHAEL BURNETT is a validation engineer in the Analog business at Texas Instruments. He earned his master’s degree in Electrical Engineering from the University of Wyoming. He joined TI in 2008 and was elected to the technical ladder in January of 2018. To fulfill his passion of preparing students for industry, Michael has collaborated with Texas A&M University and The University of Puerto Rico at Mayagüez to incorporate a validation technical elective course into the engineering curriculum for each of these institutions.

RAINER FINK joined the Department of Engineering Technology and Industrial Distribution at Texas A&M University in 1995 and is currently the director of the Texas Instruments Mixed-Signal Test Laboratory. He received his BS, MS, and PhD. in Biomedical Engineering from Texas A&M University. His areas of interest in research and education include medical product development, analog circuits, instrumentation, and entrepreneurship.

TOM MUNNS is a veteran of microprocessor and large SOC debug and development having worked at Motorola/Freescale/NXP on three generations of products namely 68k CISC, 88k RISC, and PowerPC families. Having held positions in product engineering, design, and, most recently, test engineering, Tom has professional and technical skill and interest in how DFT and DFM can improve the time to market, product quality, and eventual cost of test for high volume high visibility products. Tom’s last managerial position at Freescale Semiconductor was as PowerPC Multicore SOC test and technology manager. Tom has a BS and master’s in EE from Texas A&M University, and is currently a senior lecturer within ESET, College of Engineering, Texas A&M, supporting the TI Mixed-Signal Test Lab.