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Current Electronics Curriculum at Two-Year Engineering-Technology Programs: Academic Preparation vs. Industry Expectations

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Abstract— It is a challenge to teach electronics in career-oriented two-year programs due to the practical knowledge that must be taught within a limited amount of time. The challenge stems from the balance that must be achieved between theory and practice. There is a huge gap between the fundamentals of electronics that we are still teaching in traditional electronics courses and the real-world electronics used for building modern devices and gadgets. This survey investigates whether it is possible to teach modern electronics for modern industry, particularly in two-year programs. In an attempt to find a solution, various sources are investigated in academia, industry, and professional societies. The goal is to begin a productive discourse to find a solution to this dilemma..

Index Terms— Curriculum Development, Modern Engineering Education, Pedagogy.

I. INTRODUCTION

T HE core part of a career-oriented electrical-engineering technology program is the electronics course. However, it presents a real challenge to teach electronics today. Indeed, on the one side, we need to introduce the basics of the subject starting from diodes, transistors, and the simplest amplifier circuits; on the other hand, modern electronics is based on integrated circuits (ICs) whose operation is very far from that of the circuits build from discrete components. In fact, the understanding of a system as a whole entity is imperative in practical applications. ***In short, there is a huge gap between the fundamentals of electronics that we are still teaching in traditional electronics courses and the real-world electronics used for building modern devices and gadgets***. This gap continues to increase rapidly because electronics went through another technological revolution over the last ten years. This revolution resulted in dramatic improvements of speed, miniaturization, functionality, and other parameters. ***This situation raises the question whether it is possible to teach modern electronics, particularly in two-year programs***. Obviously, it is not the concern of our department only. This is a nation-wide problem that many experts from industry and academia have realized [1].

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II. MODERN ELECTRONICS AND TRADITIONAL COLLEGE-TEACHING APPROACH

The current rate of innovations in technology is growing at an exponential rate [2, 3], introducing conceptually new forms from "synthetic biology" to nanotechnology. Modern electronics are composed of integrated circuits that perform multiple functions of the system on a single microchip. These are referred to systems-on-chip (SOC). This technology has been based on inventions of the transistor in 1947 and the integrated circuit in 1958 and — amazingly — ***the concepts taught in the classroom have not changed since then***. ***Comparing textbooks in electronics over the past 50 years confirms this*** [4,5]. Many universities and colleges offering electrical engineering technology degrees teach the concepts of solid-state electronics using discrete components as the main method, whereas the modern integrated circuit — though introduced in most programs — has limited theory and laboratory exposure. It should be mentioned that some electrical engineering (not technology) programs introduce their students to very large scale integration (VLSI) circuits only at the graduate level. ***Thus, modern academic programs in electronics, particularly those offering two year degrees, are very much behind current electronic technology***. To further elaborate our argument, we refer you to Figures 1, 2 and 3. Consider Figure 1 [6,7], where traditional bipolar junction transistor (BJT), the BJT-based amplifier and integrated-circuit (IC) operational amplifier (op-amp) are shown. The BJT was the first type of transistors invented in 1947 at Bell Labs. We still spend a significant portion of the electronics course on discussion of the principle of the BJT's operation and BJT-based circuits even though today industry virtually doesn't use them. The IC op-amp was one of the first integrated circuits developed in the early 60s. It contains tens of transistors, is still widely used, and is part of the traditional electronic course. In reality, most of modern electronics is based on the other type of transistor called the field-effect transistor (FET). Figure 2 [8,9] shows a traditional junction FET (JFET) and the newest type—FinFET—of FET developed to meet the demand for placing the ever-increasing number of transistors in the IC circuits.

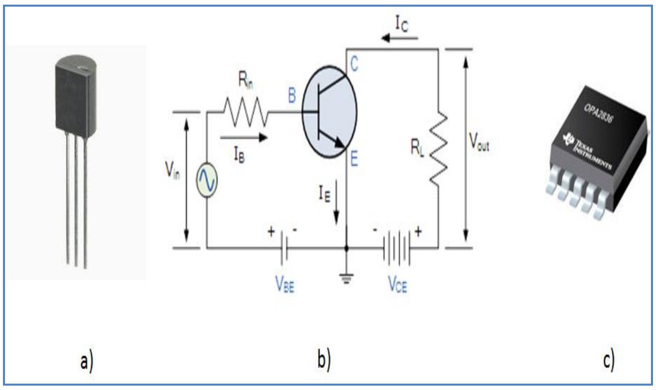

Figure 1. a) Traditional Bipolar Junction Transistor (BJT), b) BJT-based Amplifier Circuit, [6]c) Integrated Circuit (IC) Operational Amplifier [7]

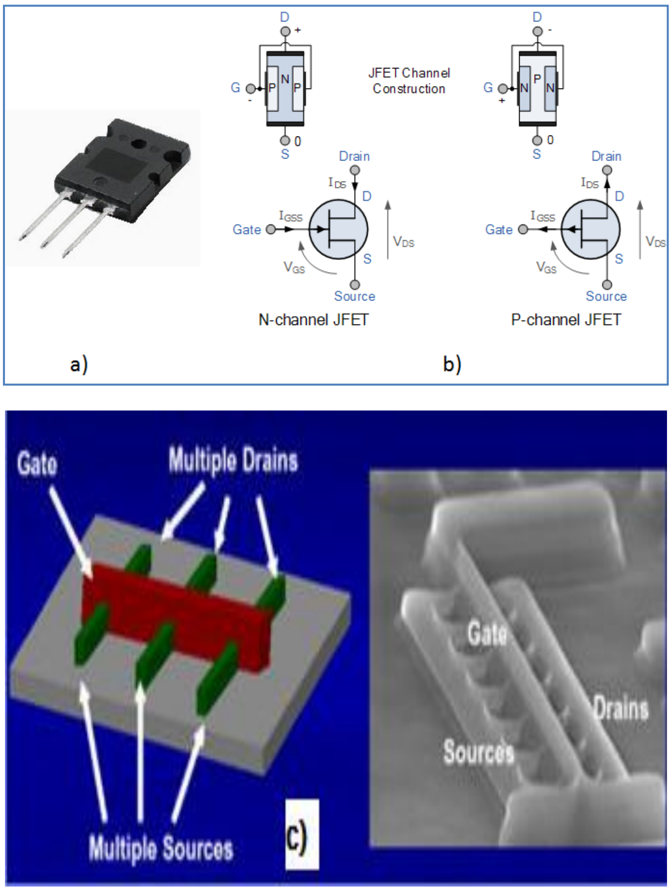

Figure 2. a) Traditional Field-Effect Transistor (FET), b) Basic Structures and Schematic Symbols of Junction FET,[8] c) the Newest FinFET Transistor. [9]

Figure 3 [10] shows the latest development in modern electronics – a complementary metal oxide semiconductor (CMOS) application-specific integrated circuit (ASIC) designed to perform digital signal processing of an optical communications signal in real time. This chip contains many millions of FET transistors and performs 12 trillion operations per second. These advancements in electronics are evident in the electronics used in cell phones and other modern mobile devices. ***These are striking examples of the gap between academic programs and current electronic technology.***

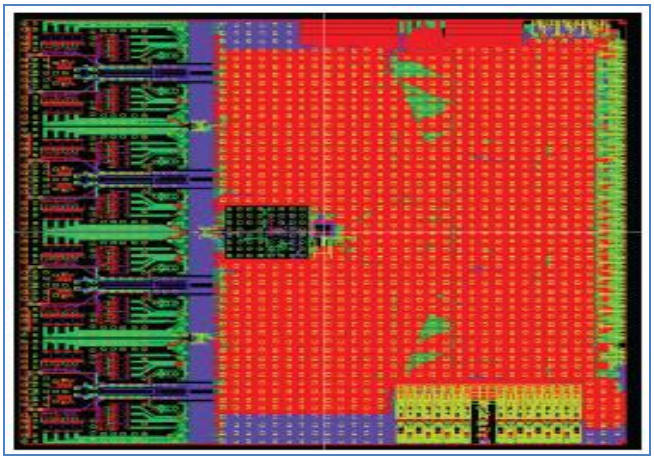

Figure 3. CMOS Receiver ASIC with Four 23 Gsample/s Analog-Digital Converters (ADCs). [10]

Clearly, the current approaches to teaching electrical engineering technology are outdated. Graduates of electrical engineering technology degrees, even at the technician level, must be more than familiar with modern electronic technology. They should be comfortable with handling it and even working with engineers in the design process [11]. This brief review demonstrates the range of the material that should be covered in electronic courses of the two-year electrical engineering–technology program. We need to start with the very basics of semiconductors and transistors and finish by introducing the principles and operation of modern IC circuits. In our department, we traditionally have an extensive theoretical electronics course and independent laboratory course, both being taught at the second semester. The other 3rd-semester laboratory course entitled *Communications Electronics* is more specialized. These three courses, clearly, are not able to cover all the needed material. We see the solution as a careful selection of the topics that must be strategically included without overburdening either the instructor or the students. ***In search of the criteria for this selection, we investigate the problem from various directions***. First, we investigated the requirements that the industry set for technicians graduated from a two-year program. Second, we researched of the academic programs at other American colleges. Third, an examination of activities of professional societies was done. These included organizations such as the IEEE, ASEE, OSA, and SPIE. In this paper we will share our findings in all these areas. ***It is our hope that our paper will stimulate the productive discussion and will lead all of us to the solution of the problem in question***.

III. INDUSTRY EXPECTATIONS

This section highlights the knowledge and skills expected from an electrical engineering technology graduate in the present job market. We focus mostly on the two-year program, however in some cases these requirements overlap with the four-year program because the expectations are based upon the material in a two-year program.

TABLE I
SUMMARY OF CORE SKILLS EXPECTED FROM A ENGINEERING TECHNOLOGY GRADUATE

Knowledge	Programming	Test Equipments	Soft skills	PC Skills	Hardware
-Circuit analysis -Networking -Electronics -Time/Frequency -Power system -System integration -Control circuits -RF Links -TCP/IP, Ethernet -Wireless standards -Test, Repair, Calibration -Schematics	-C/C++ -Java -Assembly -MATLAB -LabView -Visual Basic	-Oscilloscope -Multimeter -Power Supply -Function generator Specialized: -Spectrum Analyzer -BERT -DAQ	-Teamwork -Leadership -Oral and written skills	-A+ -Network+ -Unix -Windows -CAD -MS Office	-Fiber splicing -PLC Programming -Embedded system -Cabling -Routers, switches

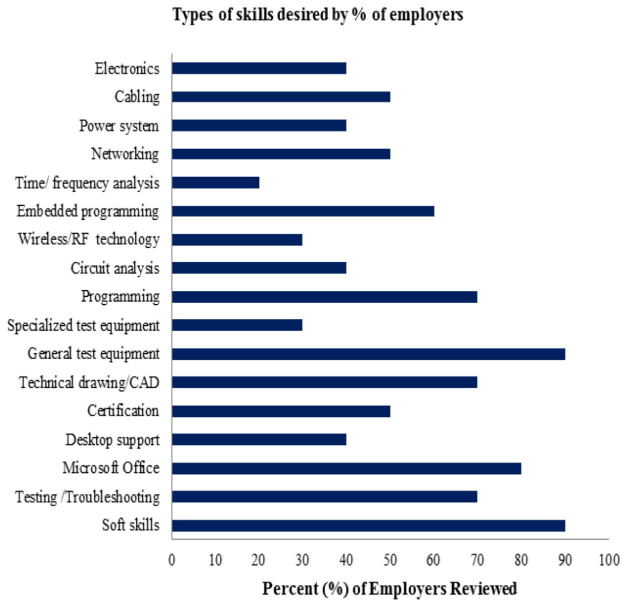

Figure 4: Demand of Skills

We contacted a number of leading industries to survey their expectations in regards to the technology graduates. In most cases, we were directed to consult the company's career website for entry-level positions. Therefore, we researched the career websites of various technology companies such as Agilent, Verizon, Microsoft, Motorola, GE, Con Edison, and Cisco to examine the industry expectations from the engineering technology graduates.[12-18] The findings are summarized in tabular form (see Table 1) to better understand the core skills expected from technology graduates. The technology curriculum should address these needs so that students are prepared for the rapidly evolving technology field. It is important to note that Table 1 shows a few of the expected skills from a number of leading industries; it does not reflect every aspect of industry expectations. The types of skills that are mostly desired by a number of leading technology employers are depicted in Figure 4. The most desired skills throughout industry are circuit analysis, understanding of schematics/drawings, working knowledge of electronic components, testing and repair, communication skills, familiarity with computers, etc. In some cases, special skills are required. It is very clear that there are a wide varity of issues to be addressed in a two-year program. The challenge is how to prioritize them and in what proportion. As we see from Table 1 and Figure 4, circuit analysis and knowledge of electronic components are still in demand, but importance of this knowledge is not that significant as it used to be even twenty years ago. The same conclusion was drawn by the authors of a similar investigation. [1]

IV. DO ACADEMIC PROGRAMS MEET INDUSTRY REQUIREMENTS?

The business of academia is to create a supply of employees that are of practical use for the industries where they will enter. In engineering technology the number of industries is wide and the depths of the responsibilities vary. ***Throughout the last half-century these responsibilities have grown and changed to the point where what used to be basic skills are now redundant. Not to say that they are no longer needed, but the depth to which they need to be known have changed.*** The change is geared specifically at the need of system-wise, rather than component-wise, design, analysis, and troubleshooting. With that in mind, a sample of institutions providing two-year degrees in electrical/electronic engineering technology was surveyed. The main items that were investigated were the programs' focus and the approach that they used (bottom-to-top or top-to-bottom) based on the program schedule and the course descriptions. (Please note that the bottom-to-top scheme implies teaching from component up to the system level; hence, top-to-bottom means the opposite approach [19].) All the schools that were part of the survey follow the bottom-to-top approach; the list of them is given in Table 2. Despite this fact, each program had some slight differences from the other. One very common, but not universal, course that was offered was typically called 'Introduction to (Electrical) Engineering Technology'. It appeared in 44 % of the schools surveyed. The course description for this class seems to consistently be an introduction to what an electrical engineer does,

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the details of the particular technology program in the school, and–in one specific case—the course bore no credit contribution at all. There was only one school with a course description that went into the different systems, such as control, wireless, power, and computer, that electrical engineering technologists work in. The bottom-to-top approach was consistent between all the programs. They began with resistors, inductors, capacitors, and then the solid-state components of diodes, BJT, and FET. The difference between the programs varies on the amount of time delegated to these courses. In some instances it was 1 – 2 semesters and in others 2 – 3 semesters. Systems are taught in all of the programs, but that doesn't come into play until the second or even the third semesters when students are introduced to logic circuits, control and/or power systems. In addition, the program outlines always follow a very broad approach as given in most all of the program descriptions, in the hope that the students will be versatile and adapt to any electrical engineering technology field: power, (industrial) control, mechanics/mechatronics, and even IC fabrication. Still, only 72% of the schools surveyed had some specialization in those areas. One university has access to an IC fab that is used for research and they offer an associate-level class that introduces students to the field. Others focus specifically on local industries that are in the vicinity of the college or university. Another school had specialization courses that focused on mechanics within the electrical engineering technology program. There's a school that has three tracks to offer for their AAS EET program, which provides students the option of the area in which they wish to gain more expertise. It is clear to see that students experience no specialization unless or until they move into four-year (Bachelor of Technology) programs, the step that is always encouraged in the program description. There are exceptions to this rule where some programs offer one specific course in either power, IC manufacturing, or computers. In fact, all of the programs have as one of the program goals the pursuit to lifelong learning and the programs are designed just so to give students the opportunity to transfer their credits to a four-year technology program. Despite what appears to be an obvious oversight by the schools in following the 'old ways', each school that is ABET accredited has an industrial advisory commission that is referred to for updating and developing their program [20]. This raises the set of important questions, 'Is there miscommunication between industry and academia? Does academia not really care to follow the suggestions that industry provides? Does industry not bother to push academia for the new system-wide troubleshooting and design techniques that they need?'

TABLE 2: LIST OF SCHOOLS SURVEYED

Alfred State College
Augusta Technical College
Brigham Young University – Idaho
Burlington County College
City University of New York, Bronx Community College
City University of New York, College of Staten Island
City University of New York, Queensborough Community College
Fairmont State University
Indiana University-Purdue University Fort Wayne
Kent State University, Tuscarawas Campus
New York City College of Technology
Northeastern University
Northwestern State University of Louisiana
Pennsylvania State University, Altoona Campus
Pennsylvania State University, Behrend College
Pennsylvania State University, Fayette Campus, Commonwealth College
Pennsylvania State University, Hazleton Campus, Commonwealth College
Pennsylvania State University, York Campus, Commonwealth College
Purdue University Calumet
Purdue University North Central
State University of New York at Canton
The Pennsylvania State University, Berks Campus
The University of Akron - Summit College
University of Hartford
Youngstown State University

V. PROFESSIONAL SOCIETIES AND THEIR CONTRIBUTION

It's important to add that none of the professional societies involved in our field—and we refer to IEEE, ASEE, OSA and SPIE—demonstrate their concern or activities in transforming the electrical engineering-technology programs to meet the current industry demands. The only partial exception, to our knowledge, is ASEE where this topic was discussed at the 2008 ASEE annual conference. [1] Even the NSF's program called Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics (TUES) did not award for the last three years any project specifically aimed at closing the gap between the academic and industrial worlds. This observation just adds strength to our questions listed above.

VI. FUTURE WORK

Since the above discussed concern is real, it deserves additional focus and effort. Therefore, we think that ***we need to fundamentally revise the structure of the current electronics syllabus for two-year programs in EET*** by *compressing* all the current basic courses in electricity and electronics to two courses, *consolidating* all the material in the aforementioned courses so that the students will study only what is necessary for understanding modern electrical and electronic technology, and *include* into the program an introductory course covering modern electronic technology.

Such an intensification of the program requires that students entering it have a firm foundation in math and science. This includes a strong analytical ability for solving problems and introduction to electronic technology. Hence, ***this revision of a college's program will require preparing high-school students for the challenge, which, in turn, leads to the need of educating high-school teachers.*** Similar methods have been used with encouraging results [21-23]. Part of the motivating rationale of this is to educate teachers on how to integrate pre-engineering concepts into their classroom with a focus on real world applications. This will require to work with 9-12 grade teachers to inform them of the ideas, concepts, and methods that they may use on their students to prepare for the new program.

VII. CONCLUSION

There is a huge and increasing gap between modern electronics produced by the industry and electronics taught at academic institutions. However, there are few distinguished efforts from academia to change the situation. What's more, it seems that both sides are satisfied with this status quo, which leaves our questions unanswered. Therefore, we intend to take this issue to the next level, as mentioned in the previous section.

REFERENCES

1. John Robertson et al., "*The Technology World Is Changing Rapidly – Can Higher Education Match the Pace?*", Proceedings of 2008 ASEE Annual Conference, June 22-25, 2008, Pittsburgh, Pennsylvania.
2. Vivek Wadhwa. (2012, June) Forbes. [Online]. http://www.forbes.com/sites/singularity/2012/06/25/most-innovative-decade-in-history/
3. A. Tavares et al., "Industry trends, learner needs," in Global Engineering Education Conference (EDUCON), 2012 IEEE, 2012, pp. 1-8.
4. Joseph J. DeFrance, General Electronics Circuits. New York: Holt, Rinehart, and Winston, 1976.
5. Robert L. Boylestad, Introductory Circuit Analysis: Prentice Hall, 2010.
6. *Electronics Tutorial about Bipolar Junction Transistors*, http://www.electronics-tutorials.ws/transistor/tran_1.html
   Texas Instruments, http://www.ti.com/
7. *Electronics Tutorial about Junction Field Effect Transistors*, http://www.electronics-tutorials.ws/transistor/tran_5.html
   Introduction to FinFET,
8. http://ziyang.eecs.umich.edu/~dickrp/eecs312/student-presentations/finfets.pdf.*Ciena*, http://www.ciena.com
9. Electronics Technician [Online] http://jobview.monster.com/Electronics-Technician-Job-Stafford-VA-125045760.aspx
10. *Jobs@Agilent*, http://jobs.agilent.com/
    VZCareers, www22.verizon.com/jobs/
11. *Microsoft.com – Careers*, https://careers.microsoft.com/
    Motorola Solutions Careers, http://careers.motorolasolutions.com/moto.cfm?page=search_jobs
12. *GE Jobs*, http://jobs.gecareers.com/
    Con Edison: Careers, http://apps.coned.com/careers/careers/list.asp?category=Skilled+Trades#20053926
13. *Cisco – Featured Jobs*, http://www.cisco.com/web/about/ac40/about_cisco_careers_featured_job.html
14. Koo, S, " Teaching Computer Communication Networks: Top-down or Bottom-up? ", Frontiers in Education, 35th Annual Conference, 2005.
15. http://www.abet.org/uploadedFiles/Accreditation/Accreditation_Step_by_Step/Accreditation_Documents/Current/2013_-_2014/etac-criteria-2013-2014.pdf
16. T.J. Cortina et al., "Work in progress: ACTIVATE: Advancing computing and technology interest and innovation through teacher education," in Frontiers in Education Conference (FIE), 2012, 2012, pp. 1-2.
17. P. Hylton, W. Otoupal-Hylton, W. Campbell, and D. Williams, "Science Bound: A success story for STEM Education," in Frontiers in Education Conference (FIE), 2012, 2012, pp. 1-5.
18. Inmaculada Plaza, Raul Igual, Carlos Medrano, and Marian Angeles Rubio, "From companies to universities: Application of R&D&I concepts in higher education teaching," IEEE Transactions on Education, pp. 308 - 315, 2013.