CAN WE TEACH MODERN ELECTRONICS AT A TWO-YEAR ENGINEERING-TECHNOLOGY PROGRAM?

ASM Delowar Hossain, ahossain@citytech.cuny.edu

Zory Marantz, zmarantz@citytech.cuny.edu

Djafar Mynbaev, dmynbaev@citytech.cuny.edu

Department of Electrical and Telecommunications Engineering Technology
New York City College of Technology of the City University of New York
300 Jay Street, Brooklyn, NY 11201

Abstract: Teaching electronics in career-oriented two-year programs is a challenge 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.

Key words: Engineering education, Pedagogy

Introduction

The electronics course for a career-oriented program in electrical-engineering technology is a core part of the entire curriculum. Teaching electronics today, however, presents a real challenge. Indeed, on the one side, we need to introduce the basis of the subject, starting from diodes, transistors and 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 that 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 for the last ten years; the revolution that resulted in dramatic improvement 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].

Modern electronics and traditional college-teaching approach

To introduce the subject of our discussion, we refer you to Figures 1, 2 and 3. Consider Figure 1, where traditional bipolar junction transistor (BJT), the BJT-based amplifier and integrated-circuit (IC) operational amplifier (op-amp) are shown. BJT was the first type of transistors invented in 1948 at Bell Labs. Teaching an electronic course, we still spend significant portion of the course on discussion of the principle of BJT's operation and BJT-based circuits even though today industry virtually doesn't use them. IC op-amp was one of the first integrated circuits developed in the early 60s; it contains tens of transistors and it is still widely used and is part of the traditional electronic course.

In reality, almost most of the modern electronics is based on the other type of transistor called field-effect transistor (FET). Figure 2 shows 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 3 shows the latest development in modern electronics – complementary metal oxide semiconductor (CMOS) application-specific integrated circuit (ASIC) designed to perform digital signal processing of the optical communications signal in real time. This chip contains many millions (!) of FET transistors and performs 12 trillion (!) operations per second.

This brief review demonstrates the range of the material should be covered in electronic courses of the two-year engineering–technology program: We need to start with very basics of semiconductors and transistors and finish by introducing the principles of 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, as the title says. These three courses, clearly, are not able to cover all the needed material; we see the solution on in a careful selection of the topics.

In search for 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 direction was the search of the work at other American colleges. Third one was examination of activities of our professional societies, such IEEE, ASEE, OSA and SPIE, in this area. In this presentation we will share our findings in all these areas. It is our hope that our presentation will stimulate the productive discussion and will lead all of us to the solution of the problem in question.

Industry Expectations from the Electrical Engineering Technology Graduates

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 from the four-year-level graduate are based upon a two-year program. Therefore, a comprehensive look into both the two-year and the four-year programs may help us to improve the two-year program and prepare students for the industry as well as for entering the four-year program.

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 of Agilent, Verizon, Microsoft, Motorola, GE, Con Edison, and Cisco to examine the industry expectations from the engineering technology graduates.[2-8] The findings are summarized in tabular form (see Table 1) to better understand the core skills expected from the technology graduates. The technology curriculum should address these needs so that the 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; they do not reflect every aspect of industry expectations.

The types of skills that are mostly desired by the number of the leading technology employers are depicted in Figure 4. As the figure shows, the commonly desired skills throughout the 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 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 used to be even twenty years ago. The same conclusion was drawn by the authors of similar investigation. [1]

Are academic institution programs meeting current industry requirements of their graduates?

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 the 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 bottom-to-top scheme implies teaching from component up to the system level; hence, top-to-bottom means the opposite approach.) 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, 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. One school even had 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. 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?'

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 2008 ASEE annual conference. [1] Even NSF's program called Transforming Undergraduate in Science

(TUES) did not award for the last two years any project specifically aimed at closing the gap between academic and industrial worlds. This observation just adds strength to our questions listed above.

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 the academia to change the situation. What's more, it seems that both sides are satisfied with this status quo, which leaves our title question unanswered.

References

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Tables and Figures:

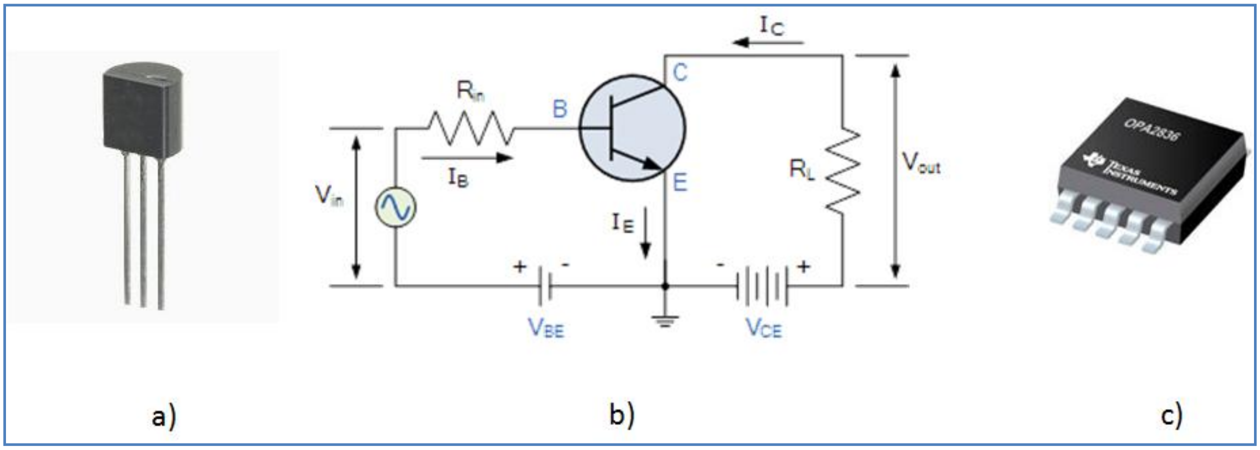
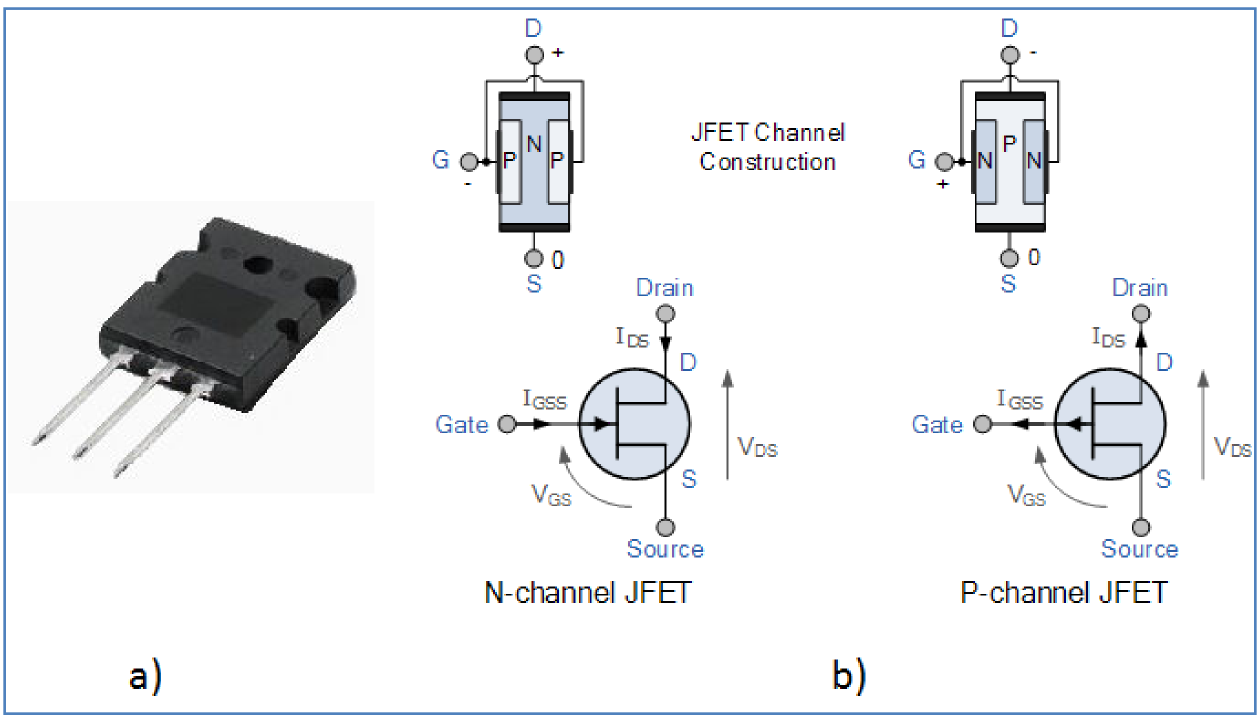


Figure 1. a) Traditional bipolar junction transistor (BJT), b) BJT-based amplifier circuit, [10] c) integrated circuit (IC) operational amplifier (op-amp).[11]



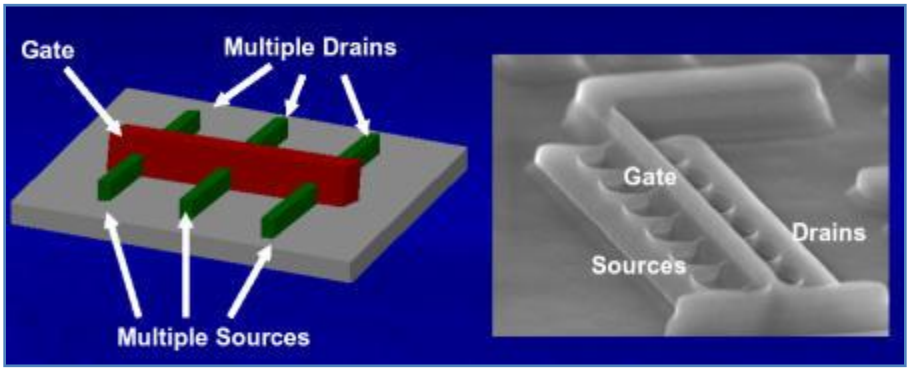


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Figure 2. a) Traditional field-effect transistor (FET), b) basic structures and schematic symbols of junction FET,[12] c) the newest FinFET transistor. [13]

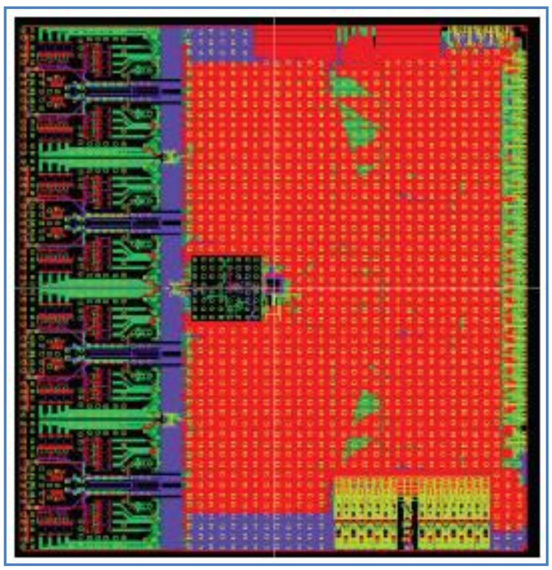

Figure 3. CMOS receiver ASIC with four 23 Gsample/s analog-digital converters (ADCs). [14]

Table 1: 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

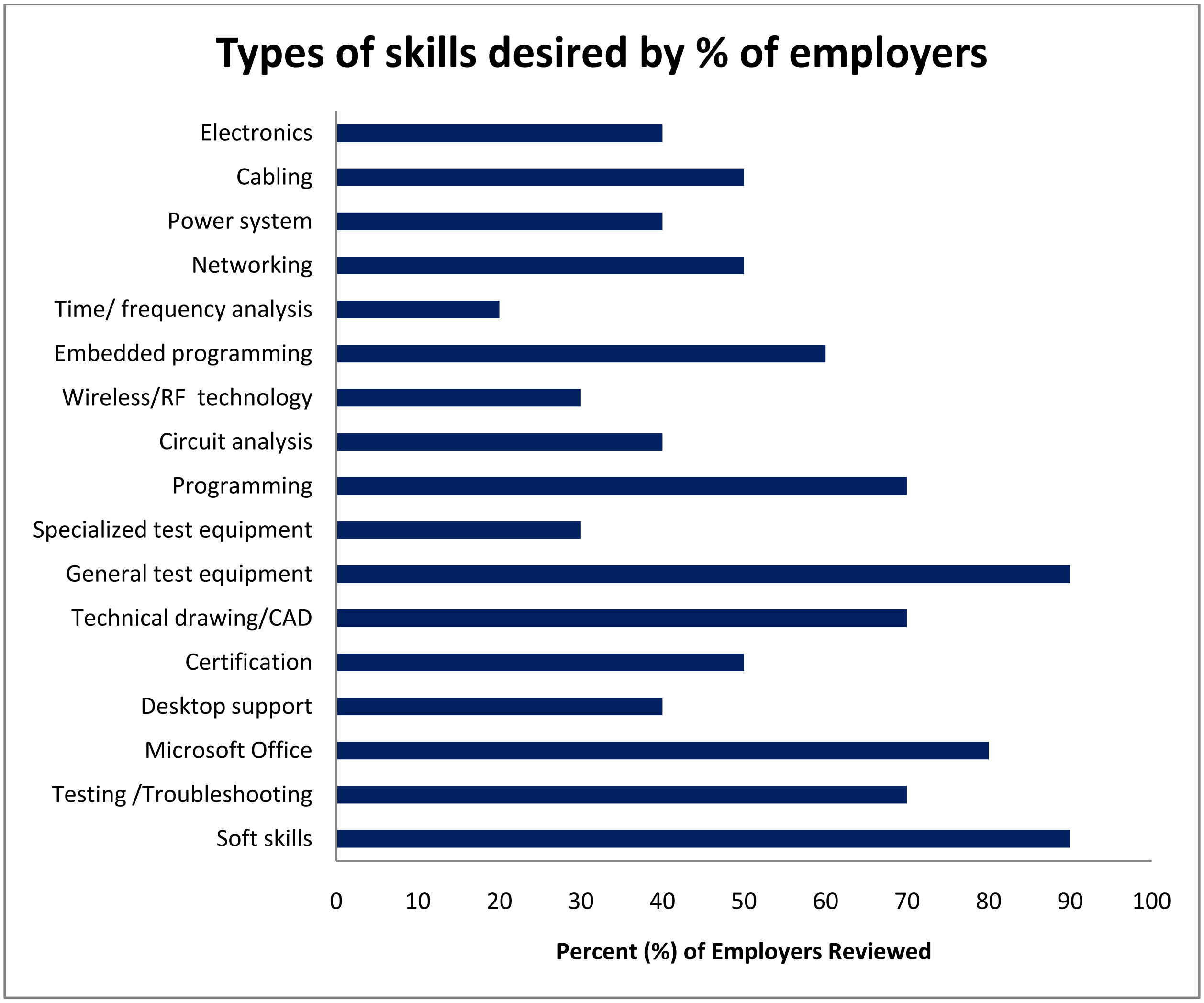

Figure 4: Demand of skills

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