AC 2011-856: INTELLIGENT INFRASTRUCTURE SYSTEMS AND THE TECHNICIAN

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Intelligent Infrastructure Systems and the Technician

Abstract
Many have written about the next transformative convergence of technologies that will surely effect how humankind will live, work, play, and age. Futurists have referred to this pending development as the "Internet of Things" to illustrate the broad concept involved. Academic and industry experts in various technical fields have coined terms like the "Smart Grid", machine-to-machine (M2M), vehicle-to-x (V2x), where x might be other vehicles (V2V) or road-side networks (V2R) or infrastructure (V2I), e-health care, and infrastructure health, among other terms, to describe discipline specific implementations of this type of technology. Essentially, through the use of networked embedded controllers (known as ambient intelligence) and complex sensors and actuators (i.e. sensor networks) the goal is to create intelligent or smart infrastructure systems that will be used to enhance the efficiency, safety, and security of human endeavors.

The Smart Grid initiative has focused attention on the question of where the technical workers of the re-engineered grid will come from. Through the American Recovery and Reinvestment Act of 2009, the Department of Energy (DOE) has awarded millions in funding for initiatives that will seek to address this question. The real question for engineering technology educators at the two-year college level should be, are there common elements to applications of intelligent infrastructure systems? The answer is an emphatic yes! Networking (both wired and wireless), network security, embedded controllers, sensors and actuators, signal conditioning, and data acquisition and fusion are the enabling technologies of the vast majority of these systems. Today, very few engineering technology programs cover these topics. An examination of ABET's present criteria for engineering technology programs finds that several of these topics tend to be mutually exclusive, belonging only in one technical program or another. Many of the topics are included in electronics/electrical/electromechanical technology programs, some others are covered in instrumentation and control systems technology programs, and networking and security is typically limited to computer technology type programs. One might consider many of these topical areas to belong to the so-called "physical layer" of the OSI seven-layer model that describes computer networking since they are the technologies that make up the hardware of the systems. Networking topics like transmission control protocol (TCP) and Internet protocol (IP) and the associated networking hardware (e.g. routers, switches, etc) and security concepts are part of the next three layers of the OSI model (that reside above the physical layer). The convergence of communications (networking) and computing technologies gives rise to a new skill set that is needed to deal with the hardware of the Internet of Things. This paper will propose an innovative two-year multi-interdisciplinary program that addresses the educational needs of a technician capable of dealing with emerging intelligent infrastructure systems.

Introduction
At this time, the present system of educating technicians in the electrical/electronics engineering technology (ET or EET) fields (or any of the closely related derivative fields) at the two-year college, Associate's Degree level is faced with an extremely important challenge as the

technology of the discipline continues to evolve. For the past two decades, educators in this field have struggled with a technology that has gone from printed circuit boards (PCBs), to a system-on-a-board, to today's system-on-a-chip technology. In retrospect, all of these evolutionary developments that have led us to where we are today, were predicted by (or more correctly, a consequence of) Moore's Law! Many two-year programs in this field have "stayed-the-course" and still teach the material like they did twenty years ago[1,2]. While still other programs have attempted to embraced a more systems oriented approach in an attempt to provide what they believe to be the up-to-date skill sets needed by their graduates. However, now along comes another new technology paradigm that threatens to stretch the ET/EET curriculum even further from its early, legacy, component centric, beginnings. This newest challenge has arisen recently, due in large part, to the upsurge of what is now being termed "convergence science" and its attendant, collateral effect on technology. What is this new challenge? It is the ability to educate ET/EET technicians in a manner that will allow them to deal effectively with emerging complex technology systems (implemented through an increasing convergence of multi-disciplinary technologies) and to be able to instill in these same students the skill sets they will need to be able to remain current and relevant in their technology field in the face of ever accelerating change.

This paper will first provide a short historical perspective of prior ET/EET curriculum drivers to facilitate an understanding of the newest drivers of this latest challenge. The case will be made for the acceptance of the reality of this new challenge and then a possible solution to the developing dilemma will be presented. However, it will first be instructive to investigate the meaning of this newly coined term - convergence science. A recently published report[3] by the Massachusetts Institute of Technology's (MIT's) Washington DC Office speaks at length to the meaning of this expression as a description of a new research model. This new model draws on a fairly universally perceived ongoing merger of life, physical, and engineering sciences. For most of the report, the frame of reference used is the field of biomedicine/biomedical/biotechnology (i.e. the life science) and its convergence with the physical sciences and engineering disciplines. Interestingly, the report also states that "Convergence is a new paradigm that can yield critical advances in a broad array of sectors, from health care to energy, food, climate, and water."[4] In other words, many of the challenges that we face as a society. The report continues by using the phrase, "The Third Revolution" to describe the effects this convergence is having on various developments in life science research. Starting with a definition of the first revolution in this field, Molecular and Cellular Biology, the report then explains the second revolution, Genomics, and finally concludes this introduction to the new model with the following hypothesis: at this point in human history, the third revolution in this field is Convergence.

Convergence is not simply a transfer of tool sets from one science discipline to another. But rather, it is the use of fundamentally different conceptual approaches from physical science and engineering being applied to biological research with a reciprocal influencing of the physical sciences and engineering by the life sciences' understanding of complex evolutionary systems. "Convergence is the result of true intellectual cross-pollination."[5]

It is this author's contention that there are strong parallels between the effect of convergence science on advances in basic research (and the subsequent creation of new knowledge) and the convergence of technology in the creation of heretofore, unthought-of, complex, networked systems (implemented with electronics devices and components) designed to improve processes and other systems and in the final analysis, the condition of humankind. At this point, it should be pointed out that some in the technology field use this term (convergence) to represent the transformation occurring in the telecommunications field where voice, data, and video are all being transported over the Internet (IP). That is not the concept that is being presented here. Continuing, if one considers a college education at the highest levels (i.e. terminal degrees), this new paradigm of convergence science translates into a need for interdisciplinary cooperation and teamwork. A researcher should have a depth of expertise in one area but should also have a wide breath of interests and knowledge. How does or will the parallel evolution of convergence technology affect the needed skills of the graduates of two-year college technical programs? The rest of this paper will attempt to make the case for a needed change in the way the education of an ET/EET technician is conducted. Although, the ET/EET field is highlighted in this paper, certainly other related fields are also affected by this paradigm shift and will be mentioned as the opportunity presents itself.

During the past decade, several knowledge leaders in the ET/EET field have presented "position" type papers [6,7,8,9,10] that have pointed out continuing problems with low enrollment and out-of-sync curricula in ET/EET type two-year associate degree programs at regional and national forums. Furthermore, at these same forums, many presenters have outlined efforts taken to combat the declining enrollments or innovative curricula changes made to these types of programs to increase student interest and enrollment. It has been pointed out by various faculty groups[11] that the continuing microelectronics evolution has transformed the field of electronics to such an extent that consumer electronics products are now disposable and many industrial grade electronics products are repaired by swapping out entire "field replaceable units" as opposed to the printed circuit board swapping of a short time ago. The repair of electronic systems to the "part" level that originally defined and drove the educational pedagogy of this field for many decades has all but disappeared. As mentioned earlier, at some institutions the response to this continuing microelectronics evolution has been to embrace a "systems" approach to the teaching of ET/EET type curricula while at many institutions (a majority in fact, according to a recent survey) a "blind eye" has been turned on the reality of the workplace[12]. There are many opinions as to why this is the way it is and this author would state that there are several inter-related, contributing factors to the problem, with some issues being more complex than others. That being the case, the resistance to change is real and substantial. At the same time, the stakes keep increasing as the students of these programs become less prepared to deal with today's and tomorrow's workplace realities. Of course, that is this author's opinion and it is certainly not shared by everyone in this field. Others will state that once given a good grounding in the fundamentals of the technology (i.e. through a component centric focus), working in the field will complete the student's education by introducing various applications of the technology. This author would counter that argument by asserting that the student will only be exposed to a narrow segment of the field by working in a particular sub-field of the technology. The student will most likely not be as well prepared to deal with the inter-disciplinary applications that many feel will most likely be the norm in the future.

ET/EET curricula: a historical perspective

Let's consider the driving forces that over time have shaped ET/EET technician education and the corresponding responses to these forces. For the first half of the twentieth century, electrical systems (the term electronics was not in vogue yet!) were usually quite rudimentary by today's standards and usually were implemented using the simple, yet venerable vacuum tube. During this era, the electrical components enabled the particular application (see Figure 1) which again was typically simplistic in nature (at least by today's standards) and also fixed in its purpose or functionality. There was usually a very basic power supply or battery, a limited number of vacuum tubes (<10) that performed analog signal processing, and a very limited man-machine interface (MMI). This interface was typically used to adjust very basic system parameters (e.g. gain, frequency, tone, etc). Examples of early applications of this type of technology would include: the superhetrodyne radio receiver, transmitters, record players, tape recorders, audio amplifiers, electrical power delivery systems, simple control systems, early tabulating equipment, the telephone system, etc.

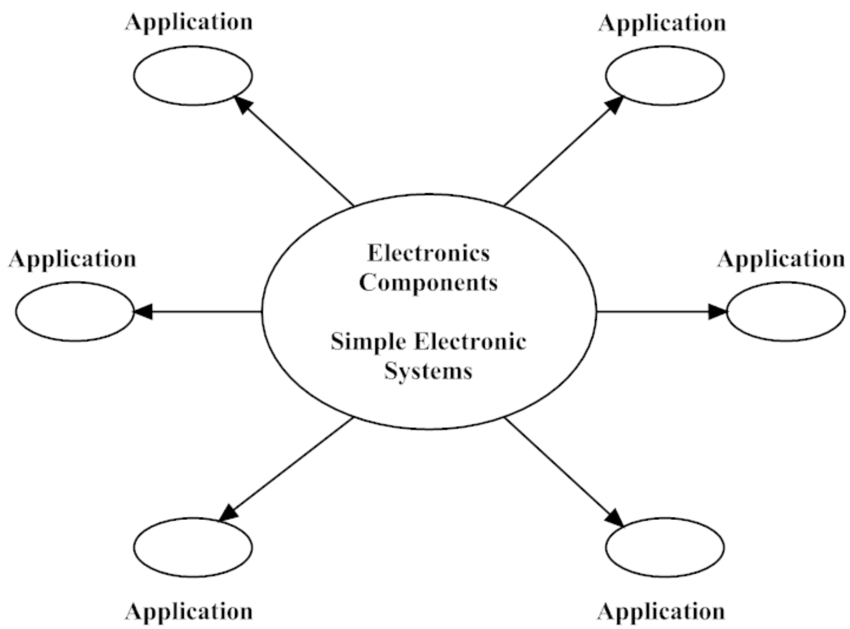

Figure 1 – Simple Early Electrical (Electronics) Systems

Curricula for these programs were designed to respond to a need to know fundamental electrical theory (i.e. DC and AC circuit theory), analog electronics (i.e. vacuum tube theory), electrical components (i.e. motors, transformers, relays, etc), and limited electronics applications (i.e. power supply, audio amplifiers, radio theory, etc). Since the components of these early systems were accessible, when a system failure occurred, the electrical technician or engineer was called upon to troubleshoot the system to the part level and effect the repair. As indicated by Figure 1, the electronic components were at the center of this technologic paradigm. The education provided to the technician of this era reflected the technology of the day and was therefore – component or parts centric. As an example of this type of pedagogy, electronic oscillators were introduced as an application of vacuum tubes not as an integral sub-system of a communications system.

The first real technology revolution to occur in the ET/EET field was driven by the invention of the computer and to a lesser extent, at about the same time, the invention of solid-state electronics (i.e. the transistor and a short time later the integrated circuit or IC). Both of these events occurred approximately half-way through the twentieth century. The last half of the twentieth century witnessed the evolution of the computer with its revolutionary ability to function under program control (and hence redirect or alter its operational flow) and the rise of digital electronics as an enabling technology. Both of these technologies were in turn enabled by the continuing evolution of semiconductor technology or using today's more common term - microelectronics technology. These quickly evolving technologies prompted an era of "curriculum accretion" in the ET/EET technology field. That is, technical programs in this field continued to add more theory into their programs (transistors [bipolar and field effect] and their biasing schemes, Boolean algebra, binary number systems, digital logic [different logic gate families – TTL, CMOS, etc], optoelectronics devices, microprocessors and microcontrollers, etc) to give their graduates detailed knowledge of these technologies and the components that were used to implement the particular application of the technology. For a while this paradigm was OK, but … after a while, programs were bursting at the seams with too much technology, usually at the expense of general education courses or a well rounded curriculum. During the 1980s and 1990s derivative technologies like computer maintenance and computer networking, laser-electro optics, telecommunications, etc began to be offered as stand-alone programs. This occurred because the amount of technical lore in these particular technology areas reached a tipping point and dictated entirely separate technology programs or options to the legacy ET/EET programs.

However, what was missing was the realization that Moore's Law was foretelling more than just the number of transistors on a chip but was also providing clues to the evolutionary change in the way one would deal with electronic systems. Figure 2 metaphorically depicts the continuing evolution of the electronic system during this time period.

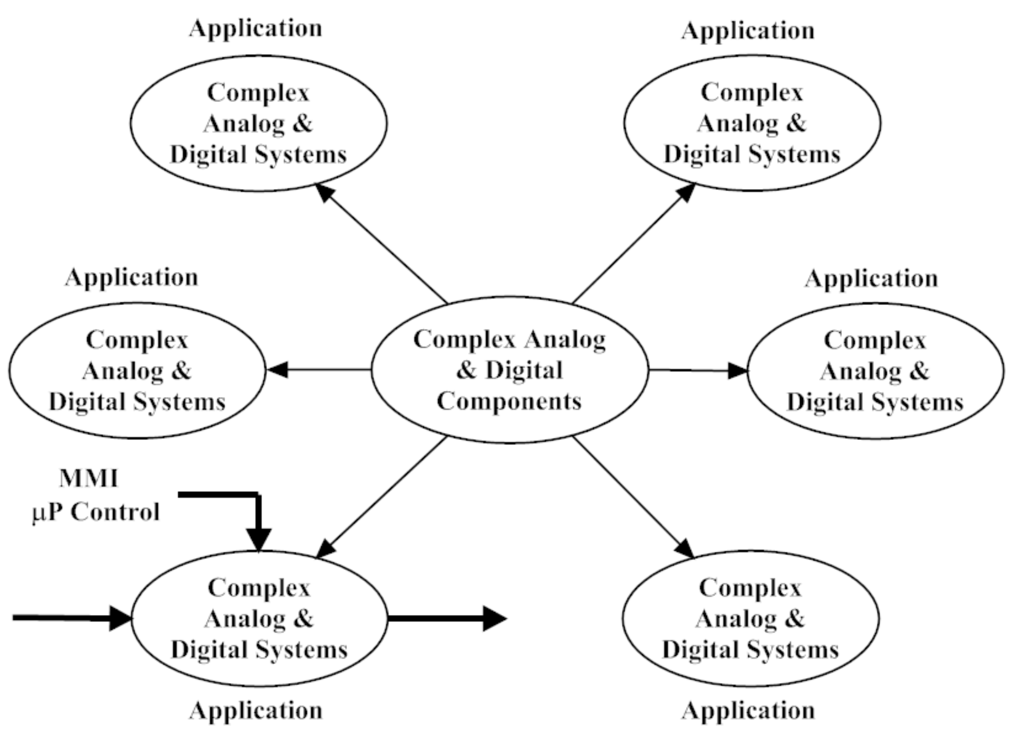

Figure 2 – Electronic systems as the IC evolves to VLSI and beyond

With large and very large scale integrated circuits (ICs) and inexpensive microcontrollers and microprocessors the complexity of electronic system designs began to grow. Now systems implemented with LSI and VLSI integrated circuit components could offer enhanced functionality, smaller footprints, and lower overall costs. The large mainframe computer was being replaced by the minicomputer and then the microprocessor and eventually the ubiquitous personal computer or PC, the cellular telephone was introduced as a personal communications device, and the electronics world was embracing the system advantages offered by digital technology. As depicted by Figure 2, the electronics itself was becoming less centric to the electronic system in terms of repair and maintenance since the components were becoming less accessible, repairable, and testable. Furthermore, the system (or application) itself was becoming increasingly important in the overall scheme of things due to its increasing functionality. As the systems became more sophisticated, they added more input/output functions and/or more user friendly human interfaces (the MMI) and microcontroller or microprocessor control to automate the system and support the increased system complexity (see the lower left-hand corner of Figure 2). A fairly good analogy to help explain this change in system complexity would be to consider the game of "Pong" released by Atari in 1972 and compare today's very sophisticated video games (e.g. Halo, Call of Duty, etc) that have very excellent life-like video graphics and more recently have embraced 3D video technology. One only needs to look around at the available consumer electronics products to understand the truly great amount of change that has occurred in this technology.

Electronics has gone from printed circuit boards that performed one function, to systems-on-a-board, to today's system-on-a-chip technology that enables present day devices like iPhones, Xbox 360s, iPads, and HDTV. Somehow, many educators in the ET/EET area were unable to correlate the reality of the field with the long-lasting and entrenched way they had been teaching these topics. From this author's perceptive, blame for this lack of change may be spread around to many areas. In physics, momentum is simply defined by an object's mass and speed. The equation for momentum does not take into account the amount of time the object has been at a certain speed! It appears that for humans the amount of time spent doing something in one way translates into an increased reluctance to change or a type of momentum that is an increasing function of time and applicable to humans only! Of course, a corollary to this concept might be that it is human nature to stay with what is comfortable (or stated differently, doesn't require work to change)! (All of this is probably a contributing factor to the so called "generation gap" between parents and their children!) More seriously, this lack of change is further complicated by a lack of appropriate textbooks that reflect the reality of the workplace. Add into the mix the publishers' desires to increase their bottom line. They continue to promote tenth editions of works that were relevant when first published decades earlier by authors who no longer write and allow the publishers to utilize ghost writers. Fortunately, there are some new texts appearing[13] that might start to alleviate this latter problem by presenting the technology via a systems centric approach.

The second revolution to impact ET/EET type programs occurred in the last decade of the twentieth century as computer networking and then the Internet came into being. The Internet has had a revolutionary impact on these programs but not just in regards to technology but in other unexpected ways. There are many ET/EET programs that out of self preservation transitioned to Cisco Networking and A+ as their core focus with the arrival of networking and the Internet. In fact the former computer maintenance technology (CMT) program at this author's college can be included in the list of earlier adopters as it quickly changed its focus to networking! So the overall effect of the Internet, networking, and the World Wide Web was to some extent: to diminish enrollment in ET/EET type programs, to now have the ET/EET programs take on the roll of service departments to support these modified programs, and also, to a certain degree, to lead to the creation of spin-off telecommunications technology programs. In the New England and New York Verizon footprint there are presently 26 two-and four-year colleges that now offer the Verizon Next Step Program that leads to an AS degree in telecommunications[14,15]. From a technology point of view, TCP/IP and digital modulation have revolutionized all facets of electronic communications and will continue to do so as the industry transitions to voice over IP (VoIP) and eventually IP television (IPTV) in both wired and wireless modes. Furthermore, the wireless data transmission evolution also continues unabated with HDTV and 3DTV and now 4G cellular technology already implemented. Our desire for mobility in terms of access to the Internet has intensified! From early on in the deployment of this type of technology, the idea of networking together PCs has led nearly everyone to associate this technology with the Information Technology (IT) field or more recently, information and communications technology (ICT). That implies that most of the applications of networking are involved with the IT functions of an Enterprise. That scenario is about to change with the onset of the next revolution in ET/EET.

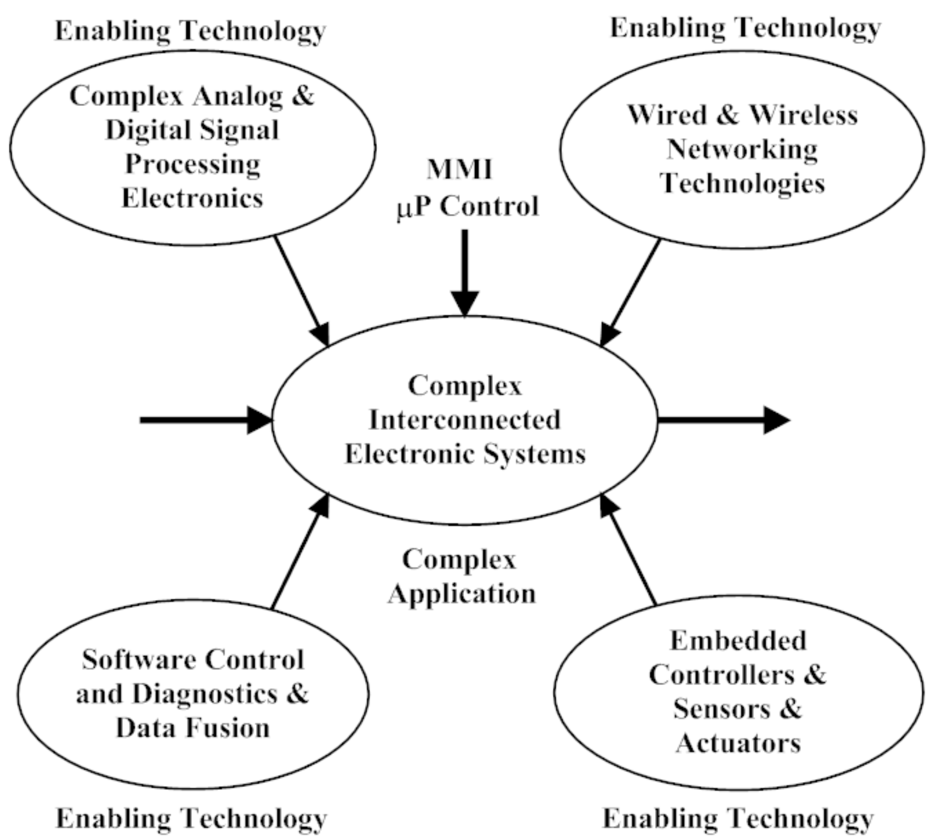

Figure 3 – The underlying technologies of the Internet of Things

The third revolution is just starting as we enter the second decade of the twenty-first century. The "Internet of Things" (IoT) is just in its infancy and its enabling technologies are depicted by Figure 3 shown above. As mentioned earlier, much like the Third Revolution of convergence outlined in the MIT report, this revolution draws on inter-disciplinary technologies and similarly has the potential to cross-pollinate the various technology disciplines in terms of what type of innovative, large scale, and high impact systems are possible.

Just what is the Internet of Things? For the past decade, researchers in many diverse fields have been exploring the possibilities of the use of sensor networks to perform a host of various tasks that in most cases are used to enhance the operation of systems or provide applications that were previously impossible to implement. This emerging technology paradigm essentially consists of the deployment of complex sensors and advanced actuators coupled with embedded (ambient) intelligence. Combining this distributed ambient intelligence with modern data-transport and networking technologies and application-enabling software gives rise to new and potentially quality-of-life changing applications and in many already existing situations, the ability to increase system efficiency, safety, and security.

Unfortunately, the high cost of deployment of such smart or intelligent systems, especially if they are geographically dispersed, and the lack of appropriate standards involving various aspects of these systems has, to this time, prevented the widespread deployment and adoption of such systems. A notable exception to the implementation of this promising technology is the automotive industry and its extensive use of sensor networks within vehicles. However, in the automotive industries' case, the economic barrier of geographically large networks does not come into play and, to a great extent, emissions and fuel efficiency regulations have been the driving force behind the adoption of this type of technology (see Figure 4 below).

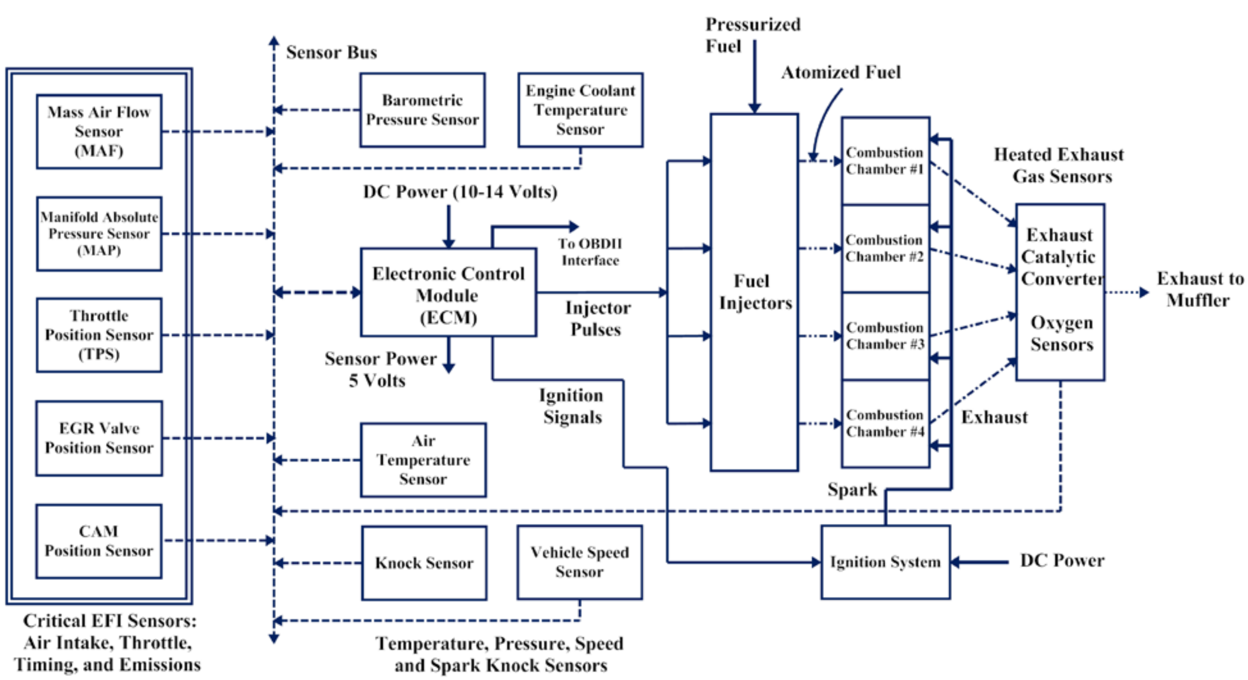

Figure 4 – Electronic Fuel Injection (EFI) system for a modern automobile

If one examines the block diagram of the electronic fuel injection (EFI) system shown above, one observes various sub-systems, sensors and actuators, and local communications buses for system communications. The automotive industry treats the components of this complex system as field replaceable units. The automotive technician, using the system's self-diagnostics (think, "Check Engine Light") and the OBDII interface, can determine the faulty sub-system and replace it effecting the repair of the system. Many of these sub-systems contain complex electronics components and systems. For the automotive industry, the application/function of the sub-system in the context of the implementation of the EFI function/system is the important aspect not the electronics components used to create the sub-system! The electronics is disposable! Anyone who has had the misfortune to have a failure of the EFI system of their automobile knows that the offending module is just swapped out without any attempt to repair it. The application is more important than the electronics even though without the electronics the system would not work! This is a very important message to educators in the ET/EET field!

Sensor Network Technology

Recently, sensor network technology has received a boost in the form of federal monies available from the 2009 American Recovery and Reinvestment Act (ARRA) targeted specially for investment in the implementation of the so called "Smart Grid". The Smart Grid is a particular implementation of a sensor network that will make our electric power distribution system more reliable, efficient, and also have the ability to sustain the attachment of distributed generation (DG) sources to it[16]. Without an intelligent electric grid, the idea of renewable alternative energy sources providing substantial power to the grid (to lower our carbon footprint) becomes a moot point. The rebuilding of the electric grid worldwide is predicted to be an initiative that will run into the 100s of billions of dollars over the next decade. This initiative will provide not just engineering jobs but technician employment for individuals with an inter-disciplinary skill-set. Furthermore, in order for efficiencies to be realized from the consumer side, the home or residence in this coming decade is going to have to become intelligent also. That requires home networking and home integration. Moreover, as plug in electric vehicles (PEVs) become more numerous, only an intelligent grid can support their use by the general population. Again, this brings a new set of electronics based technologies into the picture.

Along these same lines are e-health care initiatives that are waiting in the wings. e-health care systems are beginning to come out of the laboratory and also into the public eye as the country contemplates what to do about soaring healthcare costs and the impending retirement of the baby-boomer generation. As with the smart grid, the enabling technology of e-health care is sensor network technology[17]. Some of the proposed e-health care applications include ECG monitoring through body area networks, 2G-RFID based systems[18], human-gait tracking, emergency response[19,20], early detection of Alzheimer's disease, telemedicine, etc. For this type of application, enabling technologies that quickly come to mind are home area networks, body area networks, IPTV cameras, IEEE 802.15.4, active radio frequency identification (RFID) tags, bio-sensors, etc. Again, applications based in electronics technology.

From the perspective of one that has taught electronics technology for many years, the type of technology that has been mentioned and alluded to is a typical of the "physical layer" and in this author's opinion a more natural fit for the ET/EET technician and technologist. However, there has been little, if any, systemic support to the integration of this type of material into the ET/EET curriculum or the curricula of the many technology disciplines that are rapidly becoming users/adopters of this type of technology. For example, presently, the typical associate's degree level Energy Systems/HVAC technology student does not take courses in networking or smart sensors/actuators. Therefore, this type of person most likely will have difficulty isolating a problem or fault to the network or the complex electronics based sensor/actuator. At present, there is one active NSF ATE project that appears to be modifying and developing curricula to address these needs in the San Francisco Bay area. This Laney Community College project has identified many curricula shortcoming and is working to develop new courses to fill the perceived knowledge gaps in their long running HVAC&R technology program[21]. Similarly, the building "infrastructure health" type of sensor network might fall under the civil engineering technology graduate's job description but this technology is not typically addressed by this discipline. Present day statistics indicate that 37% of a new automobile's cost is attributable to the vehicle's electronics hardware and the software that controls it. This figure will most likely increase as time goes on and new safety features are added to vehicles that will allow them to be able to communicate with each other (known as vehicle-to-vehicle or V2V) through ad-hoc networks and with roadside information portals (vehicle-to-roadside or V2R). All of this predicted, as we move towards the deployment of an Intelligent Transportation System (ITS) for the nation's highways[22], possible by using ad-hoc wireless sensor network technology. The next Smart Grid could be the nation's interstate highway system! The possible applications and potential benefits of sensor based networks are mind-boggling! Also mentioned earlier was the impending rise in the use of PEVs that will add an entirely new dimension to the amount of electronics contained in a vehicle. How much electronics will an automotive technician need to know? Should they be exposed to more electronic systems and networking theory? Who will provide this training?

By no means is this a complete picture of what the future holds in our soon to be connected environment. But as the IBMs and Ciscos are telling us, we are staring to build a smarter planet! Meanwhile, electronics is evolving to a digital core surrounded with interface circuitry needed to connect to the real world[23] – to do stuff! The surrounding interface circuitry is the future of analog electronics – the interface between the analog world and the digital world is where analog finds its niche! What the foundations are of, what is referred to as, "electronics" are changing. This is because the field is becoming system centric. The application is more important than the electronics that enables it! Thus the new set of foundations should include those needed to understand the system and how it operates. This is a new and radically different paradigm compared to our component centric legacy.

Required Skill Sets

So, just what are the skill sets that will be needed by the ET/EET technician to deal with this developing type of technology? The ET/EET that graduates in the near future will still need to have knowledge of basic fundamental DC and AC concepts, be aware of signal characteristics, and have the ability to use instrumentation and make measurements. Additionally, they will need to be knowledgeable about: embedded controllers and have the ability to interface signals to these devices (i.e. a familiarity with sensors, actuators, A-to-D and D-to-A converters, and signal processing [amplifiers, filters, etc]), basic networking systems, wireless technologies, system structure and operation (i.e. programming, operating systems, electronic system building blocks), and the ability to perform software diagnostics/downloads. All of this coupled with knowledge of electromechanical systems and skills and dexterity with small hand tools. Like today, in the future, system failures will still occur due to power supply failures, mechanical fatigue, and interconnection problems and the technician will still need to be able to deal with these issues. But there will be new issues involving security, networking, software, and a host of system level failures that will need to be dealt with. The following table presents a list of courses (topics) that might be more germane to this "new electronics" than what is presently offered.

Course Titles	
Introduction to Networking Concepts	**Industrial Networking Technologies**
Sensors and Data Acquisition	**Sensor Systems & Networks**
Fundamentals of Electronic Systems	**Sensor System Applications**
Home and Small Business Networking	**Network Security**

Table 1

The under pinning technologies of the Internet of Things were depicted earlier in Figure 3. These technologies are: electronics, networking, embedded controllers, sensors and actuators, and software. As already stated, the technician that will deal with this type of technology will still need to know fundamental concepts in DC and AC theory, electronics from a systems (signal processing) perspective (analog and digital devices), and system interfacing (i.e. ADC and DAC, drivers, etc). Additionally, the operation of embedded controllers and how one interfaces to and programs these devices should also be considered a fundamental skill. The new material (listed in Table 1 above) needs to be layered onto these fundamentals. Topics like basic networking theory (i.e. TCP/IP) for both wired and wireless networking technologies with applications to the home environment will be a necessary skill in the intelligent or smart environment created by sensor networks. Therefore it makes sense that sensor and actuator theory should also be part of the technician's skill set and not limited to mechanical operations (e-health care applications will use many different types of bio-sensors and chemical sensors to implement their functions). Certainly, system concepts and security become important. Software and PC skills become the new tool set of this system technician replacing the DVM and oscilloscope of the past as their most important tools of the trade.

As pointed out earlier, many of these topics just mentioned are presently under the domain of different technology fields. What is being suggested here is that the skill sets needed by the technician of the future are inter-disciplinary. Development of materials from which courses can be constructed that address the topics in Table 1 will be a difficult but not an impossible task. A new National Science Foundation (NSF) Advanced Technological Education (ATE) project (DUE1003743) that has recently been funded will attempt to address these issues. Building upon a previous Course Curriculum Laboratory Improvement (CCLI) Phase I grant, the "Sensor Network Education Project, this new grant which is titled, the "Intelligent Infrastructure Systems Education Project", will be focused on developing curriculum materials, actual physical labs and simulations/virtual laboratories, and faculty expertise in this new area. An inter-disciplinary team from the technical fields mentioned previously will direct this three-year project towards its objectives. The major areas of interest for the project presently are: the Smart Grid, building automation, e-health care, and to a lesser extent automotive electronics and intelligent transportation systems.

To achieve the goals outlined in this paper, more of the ET/EET curriculum should be focused on activities and projects that involve practical systems. Starting with structured activities and projects and simple systems to more open-ended projects and more complex systems, the future ET/EET curriculum should prepare the program's graduates to deal with typical electronic systems. Furthermore, the program focus should be on giving the students experience with the evaluation of system performance and hands-on activities that allow the student to deal with the system through software and network interfaces (e.g. embedded controllers and FPLAs, etc). Moreover, ET/EET programs should become proactive in determining how they can "service" other technologies (i.e. automotive, HVAC, civil, etc) to meet the program's particular electronics needs.

Conclusion

Electrical/Electronics technology has always been one of the fastest changing technologies and today continues to morph and evolve. Moore's Law provides a number to give us a benchmark to the relative size of an IC but it does not tell us what the future holds for the ET/EET technician. We must figure that one out ourselves. Today the electronics industry is again on the threshold of another paradigm shift with the current and future levels of semiconductor, MEMS, photonic, and nanoscale device integration that are becoming possible and the convergence of these system-on-a-chip technologies with data communications facilitated by the Internet. The Smart Grid is but one, better known, example of an emerging application of this converged technology. As surely as this evolution of the web will affect how society works, plays, educates, and cares for its elderly, it will also have an ever increasing effect on ET/EET education. The electronics technician of this decade will not need to be an expert in the building or repairing of circuits but will instead need to be able to: put systems together by interfacing sub-system units, and once in place, be able to: evaluate system operation and performance through their knowledge of the system's intended function and a further knowledge of its acceptable parameters of operation. The evaluation of system operation by the technician might take place *in situ* but, more often than not, could be accomplished through a network connection from anywhere in the world at anytime and facilitated through diagnostic software and sophisticated built-in-self-test (BIST) at both the sub-system and system level. Forward-looking ET/EET programs that embrace the teaching of electronics from a systems approach, craft their curricula carefully to be systems centric and hands-on, and embrace new teaching techniques that give their students the skills to become life-long learners will be preparing their students for the technology of the future and their continued relevance in that field.

Other fields of technology will also be impacted by this most recent revolution in the ET/EET field. Any type of technology that involves some type of infrastructure or conveyance will likely be fair game for the addition of networked, ambient, intelligence. The term "Smart" has been introduced into the public's lexicon and it will probably be a complete generation before it is an expected characteristic and no longer the new thing! How this will all play out is unknown at this point, but one thing is sure, technicians in many different fields will need some knowledge about how it all works. This author believes that the ET/EET field should step forward and take the lead on this initiative.

How will this transition in the curricula of ET/EET programs be achieved? In this author's opinion the creation of an option of "Intelligent Infrastructure Technician" or "Smart Systems

Technician" added to present ET/EET programs would cause the least amount of pain and provide the easiest migration path. As another possibility, a student that already has a degree could return to school for additional course work and obtain an additional degree or certificate. As time goes on, the addition of new courses (see Table 1) in networking, sensors, and systems could be added to the curricula as the usual multiple, component centric, course sequences in electronics devices are reduced in number. Will the process be easy? Probably not. But in this author's opinion it needs to happen and sooner not later.

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