# Teaching the Media and Information Technology Major an Introduction to Engineering of Modern Communication Systems

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## ABSTRACT

The Information Revolution has had a profound impact on technical and non-technical professions. Therefore, an understanding of the basic scientific and engineering principles behind computers and electronic communication is important for students from all disciplines, especially those students majoring in Media and Information Technology (MIT). The Department of Physics and Electrical Engineering at The University of Scranton has met this need through a two semester series of courses for the non-science major entitled *Introduction to Consumer Technology* (PHYS 104) and *Information Technology* (PHYS 204). Although these courses assume no prior engineering background, they provide a meaningful technical experience that includes a quantitative approach to problem solving. This paper will outline the challenges faced teaching engineering to the non-engineering major and the topics covered in the first semester of these introductory engineering courses.

**Keywords:** Engineering Education, Media and Information Technology (MIT), Information Revolution, Technology for Liberal Arts, Principles of Communication Systems.

## SPECIFIC CHALLENGES

The most significant challenge in teaching undergraduate non-science majors about the basic engineering concepts behind modern communication systems has been the lack of an appropriate text book. Even introductory level engineering texts on communication theory are filled with complicated mathematics and enough Greek symbols to strike terror into the hearts of a typical undergraduate MIT major. John G. Truxal's The Age of Electronic Messages [15] has been a wonderful algebra-based resource of technical information that is relied on for the basic structure of this course, but this text has been out of print for several years. This leaves the choice of either obtaining the publisher's permission to photocopy this text, or to use no text at all. I strongly believe the students need a textbook to study the material outside of class, so I obtain permission from the publisher to continue to use the Truxal text, but this can not be a permanent solution to this problem. Another great textbook that may be used successfully in a similar course would be Bloomfield's How Things Work: The Physics of Everyday Life [2]. This text covers many key Physics topics and then uses those theories to describe how the things around us "work". The text contains descriptions of electric and magnetic forces, electrodynamics, resonance, electronics, optical devices, light and electromagnetic waves in 7 of its 19 chapters; however the remaining chapters of this text would not meet the goals of the particular course described in this paper. The internet provides a great resource for information and interactive learning, but can not yet completely replace a good textbook. The second course in this two-semester sequence focuses on digital signals and communication, and uses the text Information Technology: Inside and Outside by Cyganski *et al.* [4] with great success.

Another challenge has been that many of the students enrolled in this course have a difficult time with math, and have not had much experience with applied mathematics. As I present each topic, I review the math necessary for the students to be successful. Before I teach electricity, for example, I discuss the common SI prefixes used in engineering, exponential notation, and unit conversions. Some students are uncomfortable when the solution requires algebraic manipulation of formulas containing symbols. When I present Ohm's Law, for example, not only do I give the students the standard form of the equation $\Delta V = IR$, but I also show them how to manipulate the equation to solve for the current $I$, and then the resistance $R$. I do not assume that all students in the class would be able to rearrange the terms to solve for the other terms present in the equation. When we discuss sound and hearing, where dB units are commonly employed, I first review logarithms. Before I lecture about binary codes, I show the students how to "count" in binary, and teach them techniques to pass between base 2 and base 10 systems. This technical course must contain a quantitative approach to problem solving yet this may be the first exposure these non-science majors have had where math is used as an analytical tool.

Finally, it remains a challenge to keep this group of non-science majors students engaged in highly technical material. They enjoy learning the material that has obvious practical applications; electricity and power distribution, sound and speech, hearing, AM/FM radio and television, A/D conversion and digital audio. The students are very enthusiastic about live demonstrations and videos that help support the material presented in lecture. The Lucerne Media video series entitled "The Secret Life of Machines" [10] and "The Secret Life of the Office" [11] are extremely entertaining, yet contain highly valuable technical information. I have found that assignments that use internet resources are also very successful. As an example, when I discuss telephone bandwidth, I assign the students a problem given in Marshal Brain's web site [3], at <http://electronics.howstuffworks.com/telephone8.htm>. While connected to this site, they call a friend on the phone, and play a series of pure tones, from 1000 to 6000 Hz, and have their friend describe what they hear. Frequencies above 4000 Hz are intentionally removed by the phone company, and therefore these tones will not be heard by the listener on the other end of the phone line. This is a great way for the students to gain a practical understanding of bandwidth, and to learn about some of the limitations of technology. When I lecture about sound and the human perception of loudness, I provide links to web sites that interactively teach difficult concepts such as the connection between dB units and perceived loudness, and the frequency of peak sensitivity [14]. There are many wonderful web sites that support the material presented in the lecture, and make the class material more interesting and practical to the student.

## COURSE OUTLINE

This *Introduction to Consumer Technology* course begins with a discussion of the impact the Information Revolution has had on manufacturing, service industries, jobs, agriculture, and its effects on Developing Nations. In the field of clothing manufacturing, for example, the use of Computer-Aided Design (CAD) has allowed manufacturers to design patterns directly on the computer, optimize lay-out of that pattern to minimize fabric waste, and precisely control cutting machines [6]. Through the use of computer-controlled machines within the textile manufacturing industry, the cost of labor has been dramatically reduced from 30% of total manufacturing cost to as low as 4% [12]. Similar trends are seen in other industries. This, in turn, has had a dramatic effect on the number of jobs available to low-skilled workers. We discuss how the Information Revolution has brought about a change in the types of jobs available, with increasing numbers of professional and managerial positions and fewer clerical positions, and the changes in workspace requirements [1]. Finally, there is a discussion of the difficulties faced by Developing Nations that find themselves lagging farther behind as they lack the infrastructure (i.e. uninterrupted electric power and phone) necessary to support these new technologies [12].

The student is then taught basic concepts of electricity, including AC/DC voltage, current, resistance, power, home wiring, power distribution, electrical safety and energy. Students are shown the electrical wiring used in homes, and how plugs, GFI and circuit breakers function. Students learn to apply Ohm's Law ($\Delta V = IR$), for example, to study the severity of electrical shock; how the current level ($I$) is dependent on both the potential difference ($\Delta V$) and total resistance ($R$) of the shock path. Students learn to calculate the total current drawn by several appliances, and to use this information to determine if a circuit breaker would trip under the specified load. We solve problems to estimate the cost of using particular home appliances over a certain period of time, and how to read the information presented on a typical power company bill. This section is likely the easiest for the students to grasp, and there are many demonstrations to aid in the retention of the material. One such demo has both the input and output of a step-up transformer each connected to a voltmeter, ammeter, and to a light bulb to show the changes in voltage, current and power through the transformer. I give a PowerPoint presentation on electric power generation and distribution, which includes photographs of power distribution substations, transformers, the colossal high-voltage power lines that are seen along the highways, and the utility poles seen in local neighborhoods. The students then learn the history behind two key scientific advancements critical to present day electronic communications; the transistor for amplification and switching, and the development of optically pure glass necessary for fiber optics. A fiber and a low power laser pointer allow the students to witness how optical (binary) data can be transferred even through long coiled fibers.

The concepts of frequency, sine waves, harmonics, resonance, bandwidth, sound, hearing, music and speech are then discussed along with the spectral representation of these waves. Students are shown the differences between how a musician represents frequency and time on a musical staff, versus the spectrographs used by an engineer to show the same information. We discuss why each musical instrument produces its own characteristic sound, as described by the unique set of harmonics created by that instrument. Students are able to do calculations required to predict the frequency of a musical note, for example, two octaves above another, or to determine the frequencies of the harmonics. I use an audio generator connected to both an oscilloscope and a speaker for the students to get a good understanding of the connections between sine wave frequency and pitch, and sine wave amplitude and volume. Hearing and human perception of sound are discussed. Students are expected to understand the decibel (dB) unit as applied to sound levels. One resource that is recommended to the student to reinforce the concept of human perception of sound and the decibel units is the web site by J. Wolfe [16]. This site has sound files that let you hear changes in sound levels (dB units), and to measure your own hearing response "equal loudness" curve. Concepts concerning Fourier Theory and resonance are particularly difficult to conceptualize for students. Demonstrations of pendulums, springs, and tuning forks are useful to aid in the understanding of resonance, as their natural rate of oscillation is their "resonant frequency". Program 17 of the *Mechanical Universe Part I* series [8] describes common phenomena caused by resonance, such as the glass that shatters as a singer sings a certain pitch, but the video gets a bit mathematical as it introduces the set of differential equations used to model resonance. No discussion of resonance would be complete without watching the video and discussing the reasons behind the 1940 collapse of the Tacoma Narrows Bridge [13]. A demonstration of electrical resonance uses an L-C circuit, a function generator and an oscilloscope. As the frequency of the generator is varied, there is a peak output at a distinct (resonant) frequency. This leads to a discussion of radio receivers and how it "selects" one station from all other electromagnetic signals that are collected for example, by the car antenna. Projecting the spectrum of various sound signals onto a screen, using tuning forks, an audio amplifier output (sine, triangle, and square waves of various frequencies), musical instruments, and live speech, help the student understand the Fourier Theory as they hear the sound and immediately see the spectrum of that same signal. We discuss speech, and the complicated frequency patterns made as the various speech sounds are produced. These students have grown up surrounded by the fear of domestic terrorism, and are keenly interested in related topics such as how the speech spectrogram can be used to analyze and verify the spoken identity of recorded tapes of known terrorists. It is also within this section that the student learns how the telephone works, and how the speech spectrum is filtered and modulated in order to deliver many simultaneous conversations along each telephone cable. They also learn about the bandwidth of typical cables, and how the bandwidth limits capacity.

The student is then presented information on the electromagnetic (EM) spectrum, electromagnetic interference, the properties of light, human vision, antennas, radar, AM/FM radio, broadcast TV, and the biological effects of both ionizing and non-ionizing radiation. Students are expected to know the names and relative frequencies of the various EM signals, understand the relationship between speed ($c$), frequency ($f$), and wavelength ($\lambda$) given by $c = f\,\lambda$. Given frequency, students are expected to calculate wavelength and approximate antenna length ($\lambda/4$). The Secret Life of Machines [10] video series includes an episode on how AM/FM radio works ("The Secret Life of the Radio Set"), and it is easy to open a radio, attach oscilloscope leads to the connections within the case, and display an amplitude modulated (AM) signal on an oscilloscope for the student to observe. A simple demonstration of electromagnetic interference is found by cranking a Wimhurst Generator near an AM radio to hear the radio frequency (RF) static produced by the generator. This leads to a discussion on RF interference and its unintended effects on medical devices [5]. The students are taught about the biological effects of ionizing and non-ionizing electromagnetic radiation, and how the American National Standards Institute developed its current standard for electromagnetic exposure [9]. We discuss the ever-increasing sources of man-made non-ionizing electromagnetic radiation, such as cell phones and 60-Hz power, and about the vast amounts of conflicting data on their biological impact. A PowerPoint presentation is given on cell phone towers and antennas; how they are hidden within church steeples, placed on flag poles, water towers and on top of silos, and their many clever disguises as pine trees, palm trees, and my favorite – hidden within a fake cactus! A description of microphones, speakers, video recording and magnetic tapes can be also be introduced as these devices operate on the interrelated principles of electricity and magnetism.

The course is concluded with an introduction to digital signals, error correction codes, analog-to-digital conversion, the Nyquist Criterion, digital audio and digital TV. One great demonstration is to play a CD with a 5 mm hole drilled through it, and talk about how the original (analog) sound is digitized and coded onto the disk, and the error correction techniques imbedded which allow the music to play perfectly despite this obvious fault. This leads a discussion of the importance of adequate sampling rate (Nyquist Criterion), quantization, and binary representation of signals. We discuss error codes; the students learn to calculate the check digits necessary for error detection, and they learn to "send", "receive" and verify numerical messages. They are introduced to a simple Hamming Code, an efficient code used for example in satellite data transmission, and is capable of automatic error detection and correction of single errors within a digital code with the addition of a minimum number of check digits. The students are taught how product information is coded within the Universal Product Code (UPC) label, and how the information is "read" by scanners. They learn that the simple error codes used on the UPC do not allow for error correction; we all know well that "beep" tone at the check-out that signals the cashier to re-scan the misread label. This introduction to digital signals is a great lead into the second semester course which focuses on data representation, graphics and visual information, data compression, data transmission and network technology.

## STUDENT EVALUATION

Students are assigned grades based on the following; three test scores (60%), ten homework assignments (15%), one research paper (15%), and class attendance/participation (10%). This grade distribution has something for every student: the attendance, research paper, and homework scores are for the diligent student who faithfully attends every class and turns in every assignment on schedule. The tests help me to evaluate how well each student mastered the material presented in lecture. Tests contain mostly short answer questions, but there are several problems which require calculations, and there are one or two in-depth essays. These tests are not cumulative; however much of the lecture material is cumulative by nature. In the twelfth week of class, students are required to submit a five-page paper which describes some communications or electronic device, the history of its development, a description of the device and the scientific principles underlying its operation. The students often comment that they enjoy doing the research required for this report, and the chance to learn more about how a particular device (of their choosing) "works". This research allows the students to become the expert in the topic, and to present their findings to the class in a short oral presentation. This paper also serves to reassure the student that they have now gained sufficient scientific knowledge to understand the basic operation of many modern communication devices. I tell the students in advance that they must submit their research paper electronically to the plagiarism prevention website, www.turnitin.com [7]. This service generates an "originality report" on each student paper that indicates how much of the student's work matches other internet resources, and gives a side-by-side comparison of the student paper and the original web page containing the matching text. This helps to encourage the students to "digest" the information and to present what they have learned in their own words.

I then grade the student paper based on the following 25-point Evaluation Rubric, which has been designed to verify that specific tasks were performed:

- Introduction (0-3 points) A concise lead-in to the report, a statement that makes the purpose of the paper clear, and describes what to expect in the report.
- Background (0-5 points) History and development of the device.
- Report of research (0-10 points) Original discussion of the underlying principles of the device's operation. Present interesting and relevant facts in a logical order, scientifically accurate and adequately detailed. Information must not be "cut and pasted" nor overly quoted from research sources.
- Conclusion (0-2 points): The most important research findings are restated, no new information is presented.
- Writing Mechanics (0-3 points): Correct font size, spacing, margins, spelling, grammar, punctuation, page order, page length and sentence structure must be used. All ideas in paper must flow logically. References must be adequate (3 references minimum) and cited correctly.
- Attractiveness (0-2 points): Typed, clean, neatly bound, with figures as necessary.
- Timeliness: No reports are accepted after the due date. All reports must also be submitted electronically to website www.turnitin.com [7] before the due date.

## CONCLUSIONS

It is a challenge to teach this course as it must be taught at a level that educates, challenges and engages the students, without becoming overly mathematical or theoretical. Many of the students are proficient in algebra, but not calculus. Concepts such as SI prefixes, scientific notation, and logarithms must be reviewed. The student does not enter the course with a good understanding of the binary or hexadecimal numbering systems. Demonstrations must accompany more abstract concepts, and these demos help to maintain student interest in the subject. Videos help to reiterate important ideas, and give the students a break from the traditional lecture.

This course provides the undergraduate MIT major with a general literacy in the underlying scientific principles in electronic communication, and is a vital component to an undergraduate education in Media and Information Technology.

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