2006-1894: GEEK CIVILIZATION: AMATEUR RADIO AND FIRST-YEAR PROJECTS TO IMPROVE RECRUITMENT AND RETENTION IN AN ECET PROGRAM

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Geek Civilization: Amateur Radio and First-Year Projects To Improve Recruitment and Retention In an ECET Program

Abstract

This paper describes the author's current efforts and future plans to restore the path which led many of today's senior professionals into electronic technology. That path usually began in the teenage years with an interest in amateur radio and tinkering with electronics, followed by math and science courses in high school, then pursuit of a degree in engineering or technology. Unfortunately, that path has nearly disappeared over the last twenty-five years or so because of the evolution of electronic technology in ways that make it seem less accessible to tinkerers and amateur radio operators and because electronic technology is so pervasive in modern life that most people simply take it for granted. The author is attempting to restore the traditional path by expanding the use of hands-on construction projects which are intended to catch the interest of students and kindle their enthusiasm early in the curriculum, and to encourage an interest in amateur radio through radio-oriented projects.

I. The Ancient Geeks

In ancient times (mid-20th century) a technologically inclined teenager might be lucky enough to have an adult relative or friend who was an amateur radio operator (often referred to as a "ham" radio operator, or just a "ham"). He would be exposed to the nuts and bolts (or tubes and wires) of electronic technology through that person (an "Elmer", ham slang for mentor), would learn that hams were capable of communicating worldwide via HF ("shortwave") radio, and would also learn that hams often built their own transmitters and receivers either from scratch or from kits (those were the days of the fabled Heathkits and the lesser Knight Kits) using basic tools like pliers, screwdrivers and soldering irons. Building a Knight Kit Star Roamer five-tube shortwave receiver, easily capable of receiving broadcasts direct from distant places like Moscow, Johannesburg, and Quito, Ecuador was a powerful motivating experience for a 13-year-old, and he naturally wanted to build other things. Parts for electronic projects could often be scavenged from old TV sets or radios (available for the asking at the local TV repair shop) or purchased for a reasonable price at the local electronic distributor.

This teenager, having discovered and begun to develop an interest in electronics, would usually be classified by his peers (most were boys) as a geek. He would have little opportunity for a "normal" teenage social life, which would be replaced by a circle of geek friends. These became both a social and a technological support system. Many young geeks also had access to local amateur radio clubs with members of all ages and levels of technical knowledge, which were an excellent support system. Many geeks became amateur radio operators themselves before their 16th birthday (the youngest ham on record was 5 years old when first licensed, ten-year-old hams were not uncommon), qualifying for a Federal Communications Commission license by passing a written examination covering basic electronic theory and the required demonstrating skill of receiving Morse code "by ear."

Most geeks, having been "hooked" by technology at an early age, gravitated toward math and science courses in high school. There were no "computer geeks" in those days, because computers hadn't been invented (or, in the later years of the ancient geeks, were too large and expensive to be available to high school students), so the young geek had few outlets for his geekness besides amateur radio. These students were quickly identified by guidance counselors, who encouraged them to pursue careers in engineering or technology. This encouragement was not really necessary, because most came to terms with their geekness before graduating from high school and naturally chose those career paths out of a love of technology.

Ancient geek culture developed in this way partly because electronic technology was accessible to any curious person. The parts (resistors, capacitors, transistors, tubes, etc.) were large enough to easily see and handle, and circuits (like the classic five-tube radio) were relatively simple. Expensive test equipment could be done without, or could be borrowed from an Elmer. In his very entertaining autobiography[1], the geek philosopher and Nobel laureate Richard Feynman described the radio technology of the late 1920s and early 1930s as being so simple that a 12-year-old boy with a screwdriver (a really big one in his back pocket, mostly for show) could fix most radio malfunctions, which were usually caused by simple things like loose wires or burned-out tubes. Feynman tells of one man who brought him a radio with a more difficult problem, which required some analysis: "So the guy says, 'What are you doing? You come to fix the radio, but you're only walking back and forth!'" Feynman replied "'I'm thinking'", and continued to pace while he analyzed the problem. Before long he had a simple solution and fixed the radio. Feynman goes on to say of this customer, "He got me other jobs, and kept telling everybody what a tremendous genius I was, saying, 'He fixes radios by *thinking!*'"

II. The Modern Geeks

In modern times, personal computers have become very cheap and widely available, so most teenagers have their own. If they want to communicate with others next door or around the world, chatrooms and instant messaging services are at their fingertips for good or ill. MP3 players (some with video capability), camera phones, and personal video game systems have become standard teenage equipment. Electronic technology is so pervasive that many young people who have grown up with it do not think about it and hardly even know it is there. Modern geeks usually become geeks by discovering that they can write software for their PCs using inexpensive or free development tools, but do not automatically discover that there is anything interesting to learn about hardware. The phrase "computer geek" might as well be one word, and teenage geeks are seldom exposed to electronic hardware technology of any sort.

Geeks and those who would have been geeks in earlier times often dismiss amateur radio (if they have heard of it) as an "old man's hobby" because they never hear about the state-of-the-art aspects of amateur radio: digital communication modes like PSK-31[2] Digital Radio Mondiale (DRM), GPS/APRS (Automated Packet Reporting System)[3,4], software-defined radios (SDR), amateur radio communication satellites, amateur Wi-Fi (802.11) networks, long-range communication via meteor scatter, and on and on. As a result, fewer young people are becoming hams in the USA, although anecdotal reports indicate that this is not necessarily the case in the developing world (Eastern Europe, Asia, and the Arabian Penninusla) where governments often see encouragement of amateur radio as one way of developing needed technical skills.

As electronic technology has become more pervasive and less visible, advances in manufacturing have made it seem to be less accessible to hobbyists, tinkerers and radio amateurs. In particular, surface-mount technology has become nearly universal. Through-hole integrated circuits and other parts which could be assembled using an ordinary soldering iron are becoming hard to find. Local electronic distributors who used to sell a good variety of electronic parts have been absorbed by mega-distributors with no local presence. Even Radio Shack hardly carries any electronic components in its stores, although some are still available through the website. These developments have made it difficult for a young person with no support system to experiment with electronics, either as an amateur radio operator or as a lone tinkerer. As a result, an important path which used to lead young people into careers in engineering technology has been lost.

III. A Geek Revival

The resulting decline in electronic tinkering and amateur radio among young people over the last 25 to 30 years can be blamed on two factors: the gradual disappearance of support systems for young people who become interested in electronic technology (or who would have become interested if they had had the opportunity) due to the aging population of amateur radio operators in the USA and the perceived inaccessibility to "basement experimenters" of electronic technology. Restoring the support system for young geeks should solve both problems. Electronic technology has not really become less accessible, but the techniques have changed. Providing support to interested young people would include teaching them to use the new techniques, such as using a modified toaster oven instead of a soldering iron. More young people would become involved in the hobby of electronics, so electronics and amateur radio would begin to be a young person's pursuit again, and more young geeks would strengthen the support systems.

The university may be one of the best places to begin rebuilding geek support systems. At IPFW, very few incoming freshmen have ever built an electroinic project. During the first three semesters of the ECET curriculum, they perform lab experiments by wiring and testing simple circuits (counters, amplifier circuits, etc.) on solderless breadboards. These circuits reinforce a particular aspect of circuit operation, but do not do anything useful or entertaining, and they are torn down at the conclusion of the exercise. In the fourth semester all students take the Electronic Fabrication course, the capstone course for the AS EET degree. For most students, it is the first time they build an electronic device which does something useful or fun and which is not immediately dismantled. Many students find this, like a 13-year-old building a Knight Kit radio, a powerful motivating experience. It would be even more valuable to provide that experience much earlier in the curriculum, in the first or second semester, by encouraging or even requiring students to build projects which are useful or entertaining, or both. Interested students could be encouraged to become radio amateurs by promoting projects related to amateur radio and by establishing an amateur radio club (with a club radio station) on campus. This could then serve as a platform for K-12 outreach in cooperation with area schools, which would rebuild the support system for younger geeks and serve as a "feeder" system for the university.

Shortwave Receiver Replaces Flashing Arrow

Student projects should be useful teaching vehicles, but they should also capture the imagination of the students. At IPFW, students are required to build projects for the first time in the fourth-semester Electronic Fabrication course. Until recently, the first required project was the

"Flashing Arrow" (an array of LEDs in the shape of an arrow were flashed on and off by a PIC microcontroller) which was built by each student in the class.

Students seemed to get a lot of satisfaction out of building the Flashing Arrow and seeing it work, even though it didn't really do anything useful or entertaining. Most students began fabrication of the Flashing Arrow late in the semester, and many were still working on it as late as the last week or two of the semester, which left little time for completion of the second project. As a result, although the success rate for the Flashing Arrow was very good, the success rate for the second project was not. In the fall of 2005, The Flashing Arrow was replaced by a simple regenerative shortwave receiver in the hope that it would be more interesting to the students. Regenerative receivers were the first construction project for many hams (because of their simplicity) until the early 1970s, and this one was based on an article published in a very reputable amateur radio publication, *QST* Magazine[5]. Each student built a receiver, and one student received a broadcast from Beijing, but the overall success rate was less than 50%. The reasons for this are not known, but it is possible that the design was not as sound as hoped.

For the spring, 2006 semester, the regenerative receiver was replaced by a software-defined radio (SDR), which is both simpler and more sophisticated than the regenerative receiver, and it is hoped that the success rate will be close to 100%. Surface-mount technology is used throughout, requiring the students to learn to use up-to-date technology in place of the through-hole technology which was used previously.

The Karaoke Device Project

Before starting work on the SDR project, the students build a new project which they begin working on the very first day of the semester. This project, called the Karaoke Device, is very simple but entertaining, should have a very high success rate, and should be completed early in the semester.

The Karaoke device uses a quad operational amplifier to invert one channel of a stereo signal from an audio device and sum it with the other channel. This has the effect of canceling the lead vocal track from most studio recordings. Electronic Work Bench Multisim 8 and Ultiboard 9 were used to capture the schematic and design the PCB layout, which are shown in Figures 1 and 2 below:

Figure 1: Karaoke Device Schematic

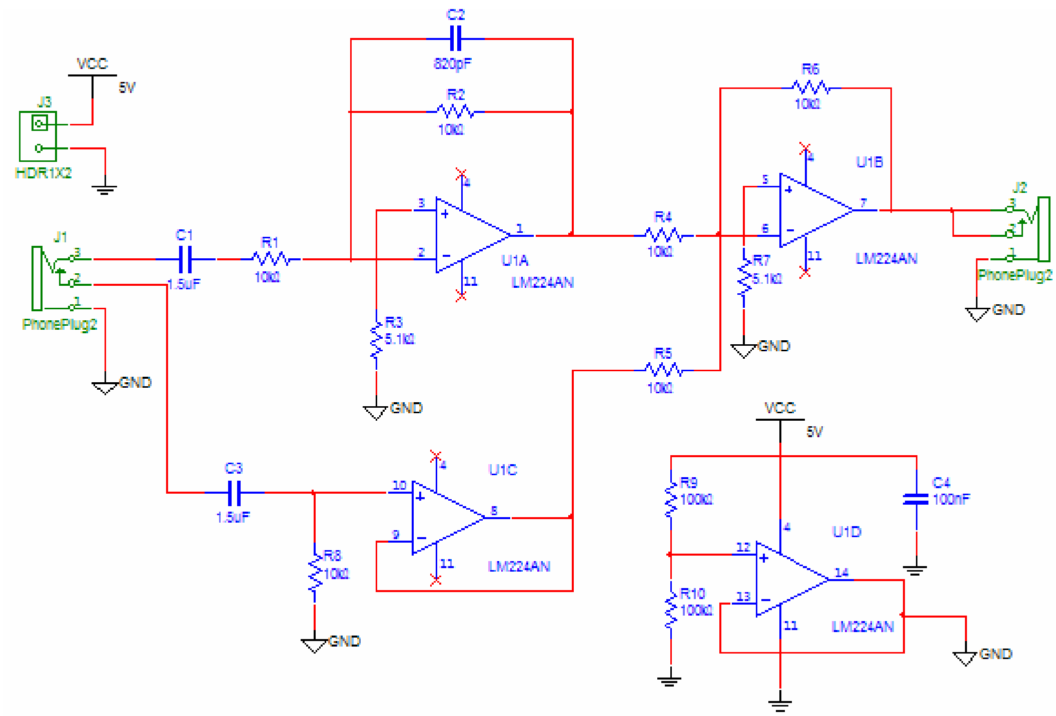
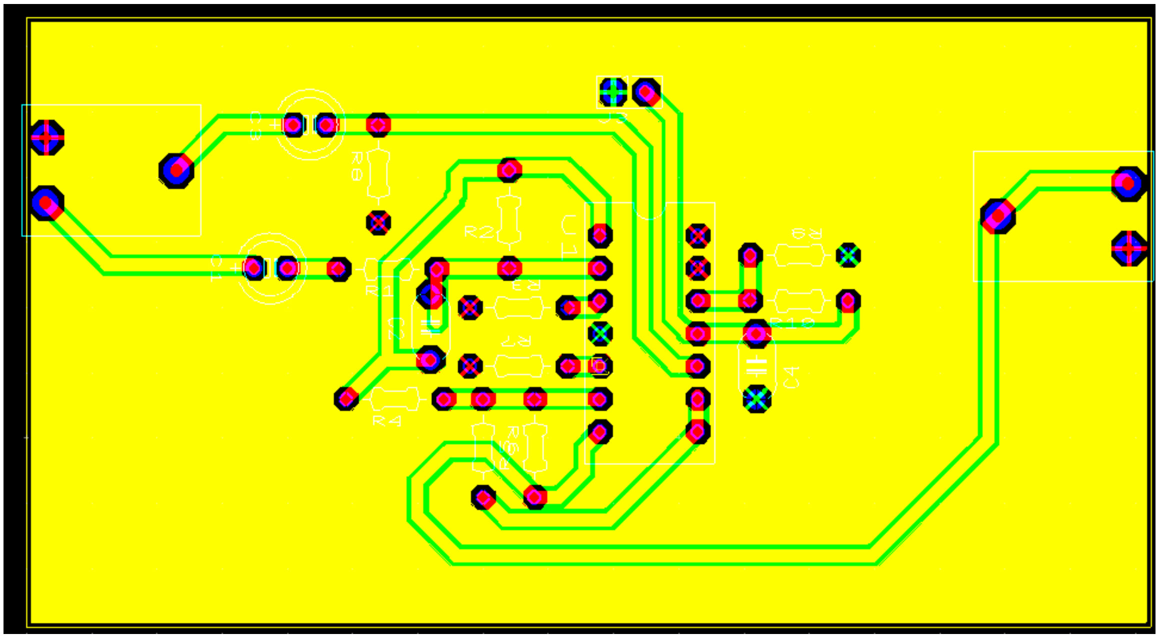


Figure 2: Karaoke Device PCB Layout



The students use these as a reference design, but are required to draw their own schematic diagrams and PCB layouts. Through-hole technology is used, requiring the students learn to solder components to a PCB by hand with a soldering iron.

The Software-Defined Radio

The SDR project is intended to expose the students to interesting and sophisticated technology and to amateur radio. It is the front-end hardware portion of a very basic software-defined radio, which uses digital signal processing techniques to implement most of the radio's functionality in software hosted on a PC. It is built using surface mount technology throughout, exposing students to that technology and to simple techniques for building surface mount prototypes. The radio operates in the "20 meter" amateur band, just above 14 MHz, which supports worldwide communication with low power transmitters when conditions are good. The SDR hardware comprise a quadrature local oscillator and a pair of undersampling balanced modulators in a configuration called the Tayloe detector. These produce in-phase and quadrature signals which are then fed into the two channels of a PC soundcard which digitizes them, and are demodulated by the free SDR software hosted on the PC[6,7,8,9]..

The reference schematic diagram and PCB layout are shown in Figures 3, 4 and 5:

Figure 3: SDR Project Schematic, Page 1

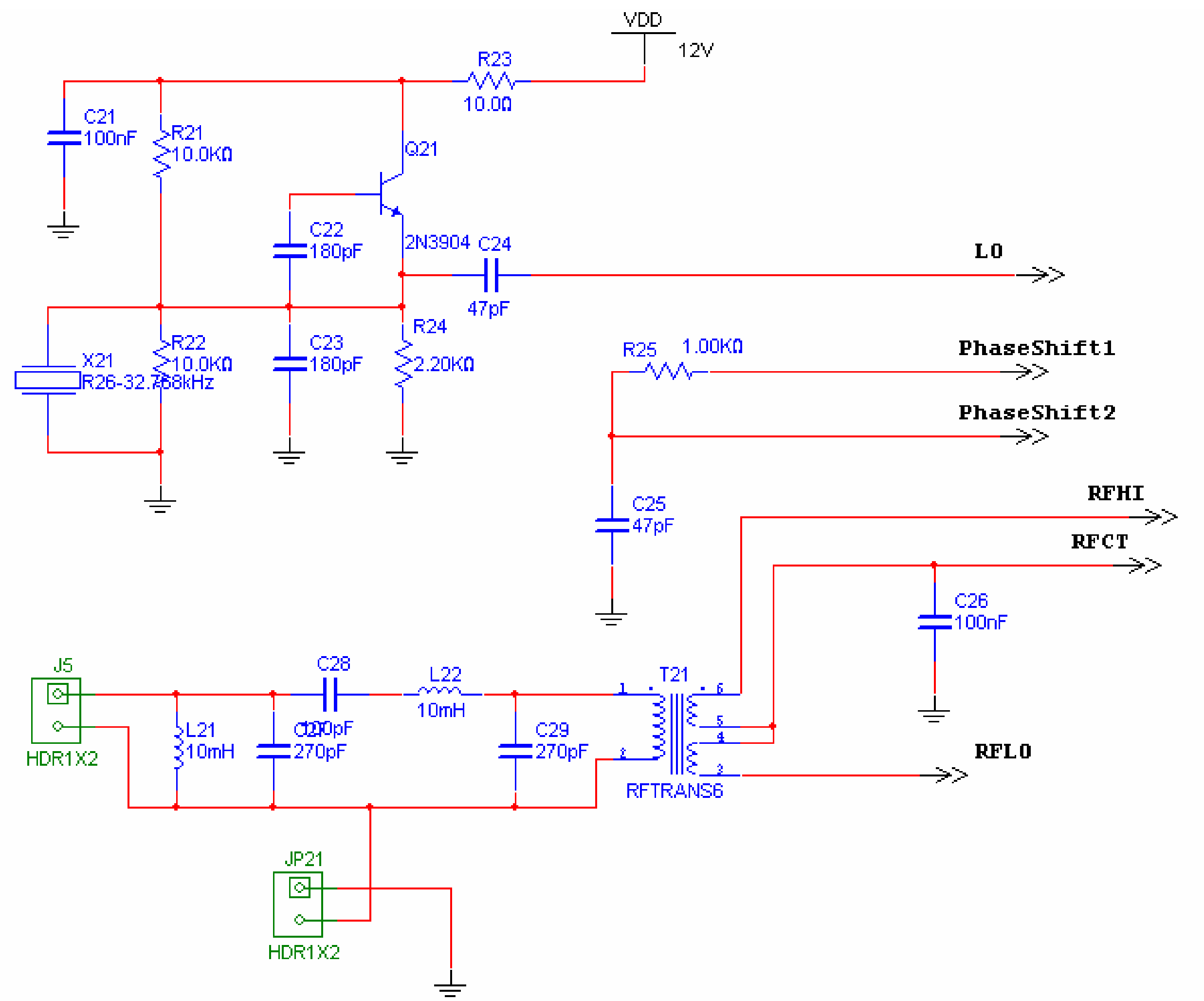


Figure 4: SDR Project Schematic Page 2

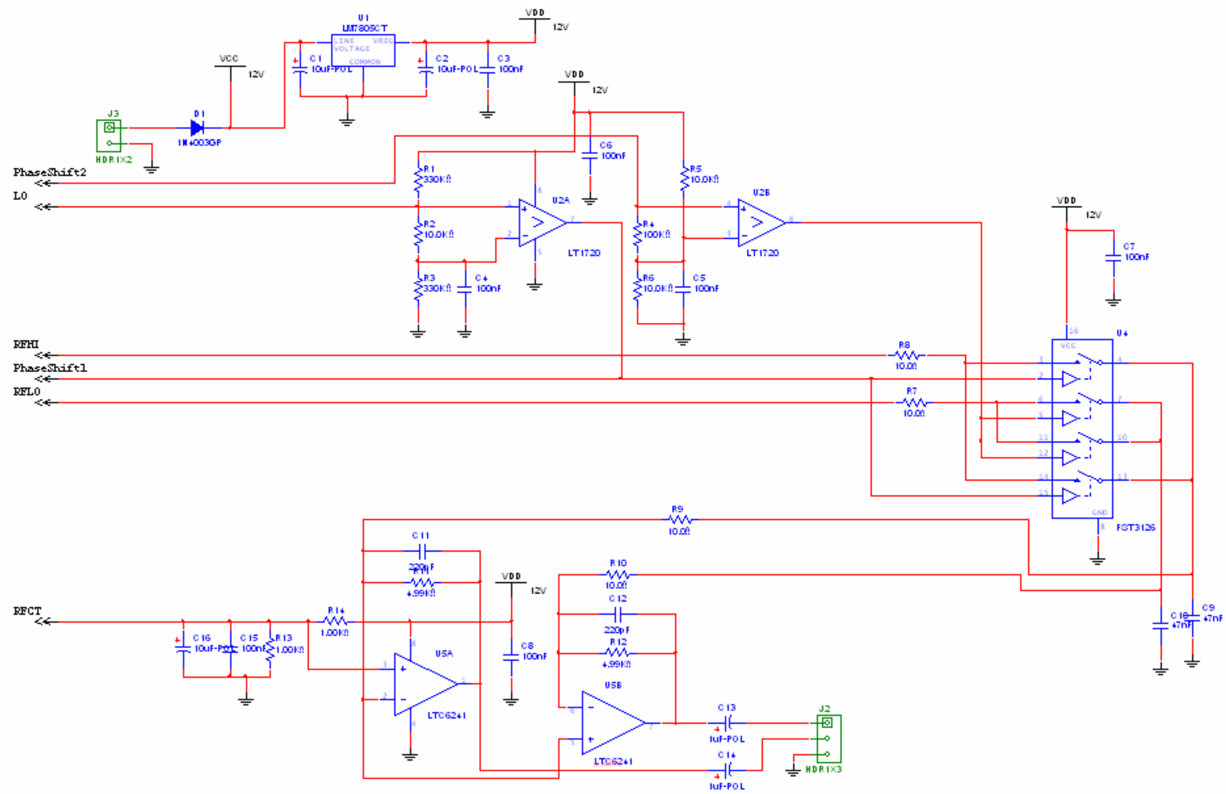
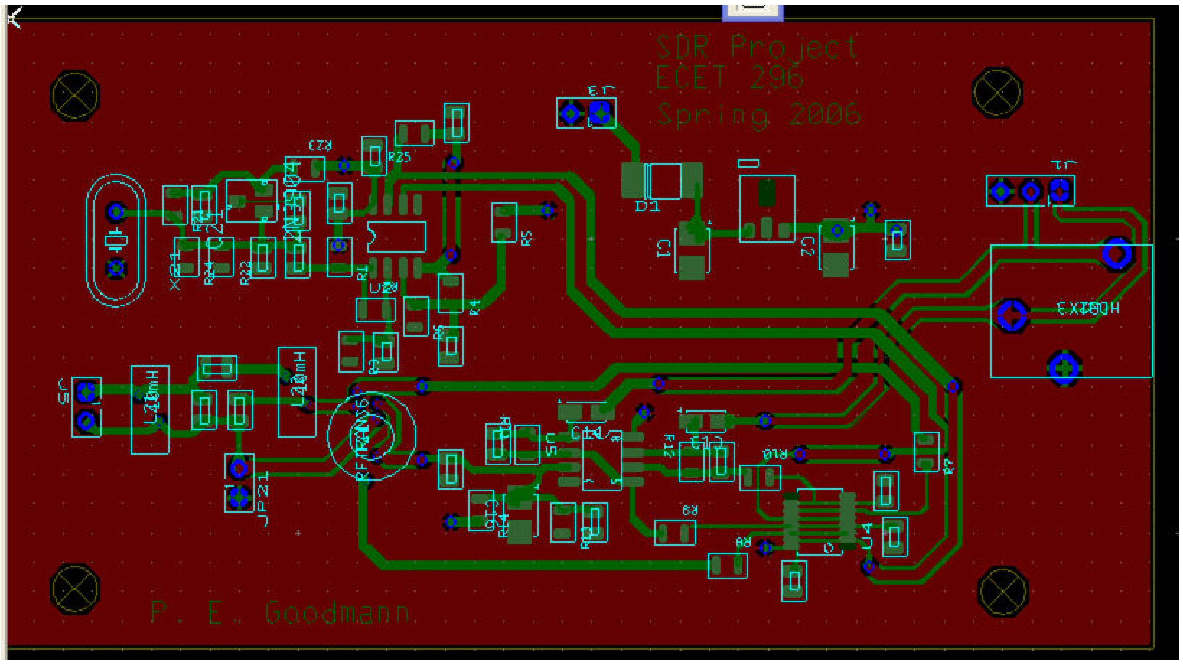


Figure 5: SDR Project PCB Layout



The hardware is a modified version of a popular amateur radio project, the SoftRock-40 (version 5)[10]. Because of its simplicity a success rate of nearly 100% is expected, so each student taking the class will leave with a fairly sophisticated, high-performance 20-meter receiver.

First-Year Students and Projects

These improvements to the Electronic Fabrication course don't directly affect students until the fourth semester. Enthusiasm for technology should be developed starting with the very first semester, by introducing them to useful and fun construction projects. First year construction projects should be incorporated into the curriculum either as requirements of first-year courses, or on a voluntary basis for the enjoyment of students, or both. Amateur radio seems to be a good way to do this

Amateur Radio in the Twenty-First Century

The Fall, 2005 DC Electrical Circuits class was given a brief demonstration of my amateur radio station, which was very well received. Although the radio transceiver and antenna were located at my home, I was able to operate them from my laptop computer in the classroom using a freeware application called Ham Radio Deluxe[11] which provides for remote operation with a server running on the home PC (connected to an amateur radio transceiver via a serial port) and a client running remote computer. The transmit and receive audio channels were carried by a freeware VOIP (Voice Over Internet Protocol) application called IP-Sound.[12] The PSK31 digital mode was used, and the students saw something similar to Figures 6 and 7. Notice the "ticker" strips going across the screen. Each ticker carries text from a different transmitting station, and all are within the bandwidth of one voice. Of those in these screen shots, one is located in England, another in Italy, and a third in Mexico.

Figure 6: PSK31Deluxe

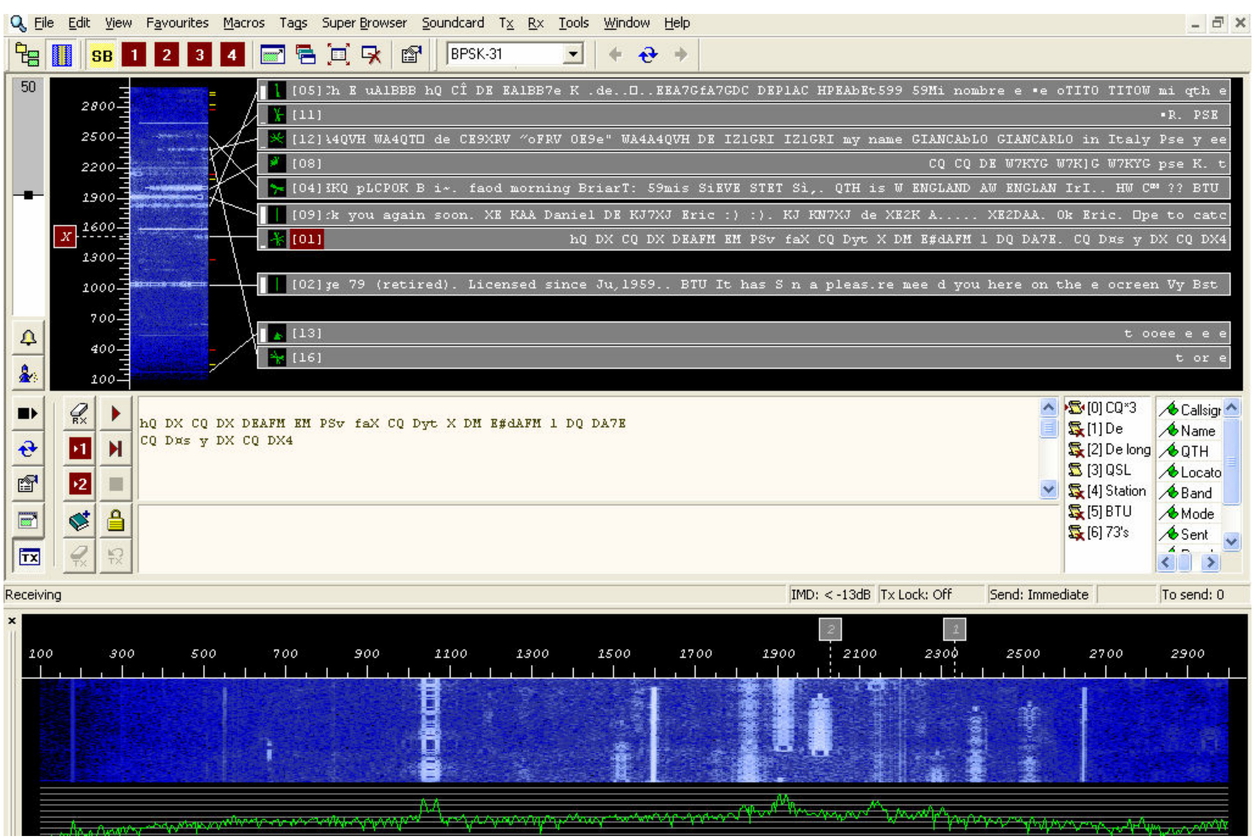
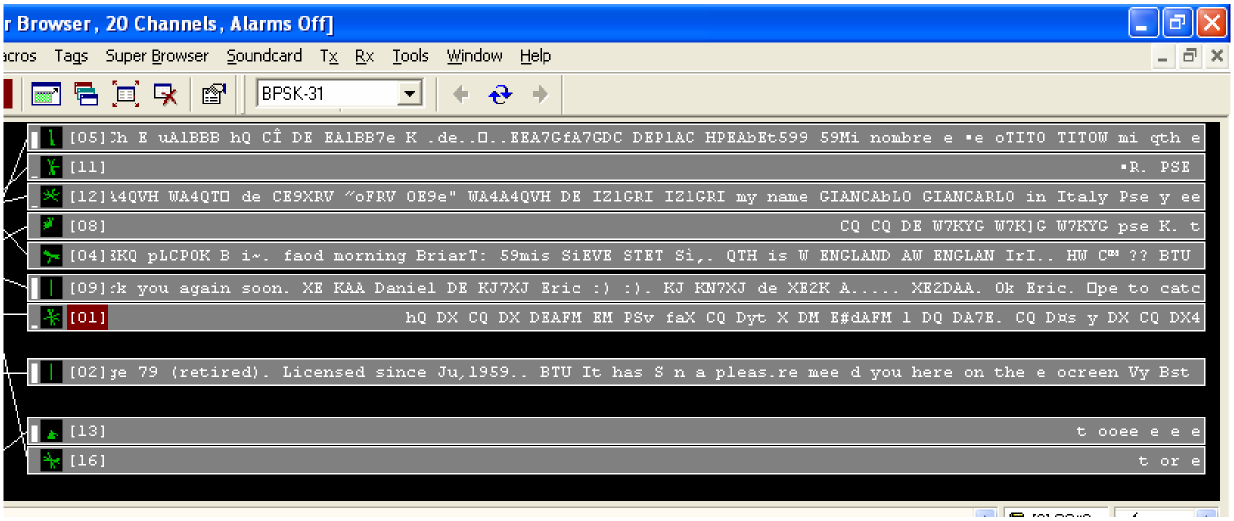
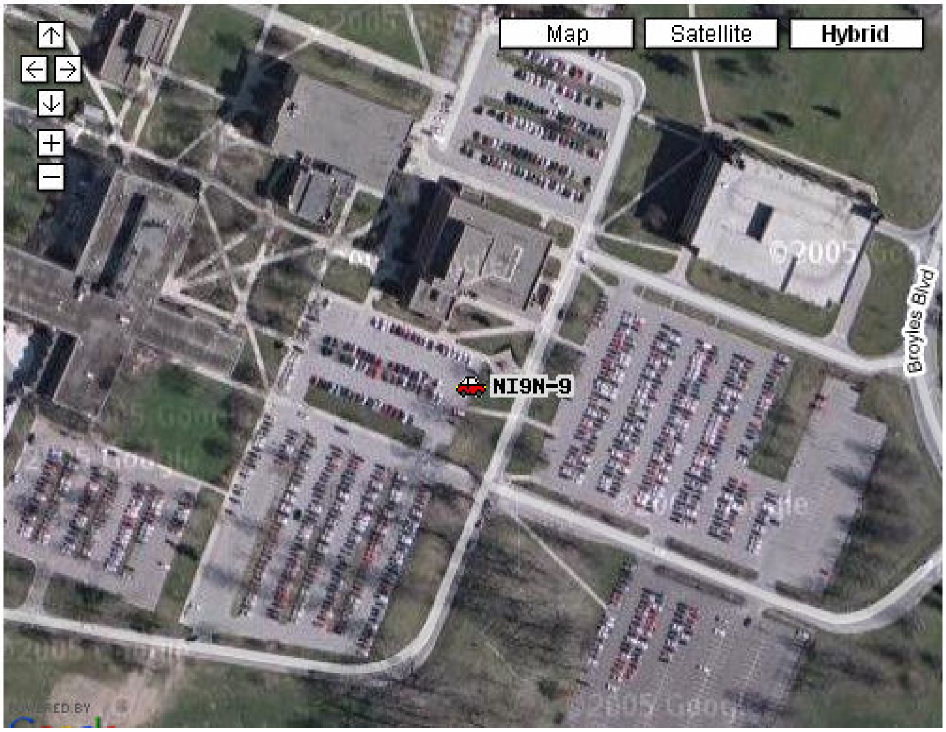


Figure 7: PSK31 Deluxe



Later that semester, the author demonstrated a pocket-size GPS tracker, which he had built from an inexpensive kit[13]. The tracker is built into an Altoids tin and connected to a GPS receiver which is not much bigger than a postage stamp[14], and periodically transmits its coordinates automatically onto the amateur radio packet network. It is automatically relayed to an internet gateway, where it is placed into a national database which is updated constantly. The location of the tracker, which was in the instructors car parked outside the building, is available on a public website, www.findu.com. It can be overlayed on a map, or a satellite overhead photo, as in Figure 8:

Figure 8: Location of the Author's Car Parked at IPFW ET Building



Too Much Enthusiasm

These demonstrations paid off in an unexpected way. Having been impressed with the tracker demonstration, a group of students expressed eagerness for a construction project of their own. The author was unprepared for this, and could offer only encouragement. Nothing happened until nearly the end of the semester when one of the students discovered a description of a very simple, inexpensive "micro railgun"[15] and asked if help might be available. The author was initially as enthusiastic as the students, but decided to consult the Chair because of the potentially hazardous nature of the project. The Chair's reaction was less favorable (in keeping with the holiday season, his exact words were "You'll vaporize your eyeballs!") because of liability concerns, but he advised the instructor to answer questions related to the railgun as long as it remained off campus and no faculty was directly involved in the project's construction. Within two weeks the students had built the railgun, and sent the author cellphone-camera video a test firing. They then asked for guidance on construction of a really big bank of capacitors to power a larger version. Students like these must be encouraged, but it is probably wiser and better for for retention, to try to redirect them to less hazardous projects.

IV. Anyone Can Do it

One way to encourage enthusiastic students while keeping them alive is suggested by the Ancient Geeks. Enthusiastic students can be introduced to amateur radio by sponsoring a simple amateur radio-oriented construction project. The SDR project described above is ideal, so it is being opened up to any student who wants to participate. Those who are not enrolled in the Electronic Fabrication course will pay $18.00 for parts and a PCB, but they will not have to design the PCB or turn in a report. Eight students have signed up at this time. Those who become licensed radio amateurs will be offered the opportunity to build an add-on transmitter at a later date, which would give them a very low-cost amateur radio station capable of worldwide communication. It is hoped that these students will become the nucleus of a support system for other students, and will also participate in K-12 outreach activities.

Other simple projects could be offered to or required of students in the first and second semesters. A dual- or triple-voltage regulated power supply would be another project suitable for the first semester, and could be used as lab equipment in subsequent courses. An "electronic coin flipper", a common hobbyist project from the 1970s consisting of a multivibrator, a latch, and two LEDs could be incorporated into first semester Digital Circuits course. A simple direct digital synthesizer (DDS)-based function generator[16] could be incorporated into the second-semester AC Circuits course, then used as a signal source for subsequent experiments. The Karaoke Device could be moved to the third-semester Electronics course. Some or all of these steps will be taken in 2006.

In The Upper Divisions

The use of projects like these can also be expanded into upper-division courses. This spring's Digital Signal Processing class, taken by most students in their sixth semester, is developing its own an implementation of the DSP software for the SDR project, to run on a Microchip DSPic instead of a PC. Next fall's Electronic Fabrication class will then build a new version of the SDR including a DSPic and student-developed software, resulting in a PC-independent SDR.

V. Inexpensive Surface Mount Techniques

State-of-the-art student projects require the use of state-of-the-art construction techniques, and that means surface-mount technology. Traditional assembly techniques such as hand soldering work poorly with surface mount parts if they work at all. Hand soldering high-pin-count, fine-pitch packages like 100-pin quad flat packs is practically impossible, so new techniques need to be adopted for student projects.

Reflow ovens are available for as "little" as $4000, but that cost may be prohibitive to small ECET programs. It is definitely too much for radio amateurs and electronic tinkerers, so the more creative ones have developed low-cost techniques such as adapting a $50 toaster oven (available at the local Target store) for use as a reflow oven.

Solder paste can be applied using a laser-cut stencil, as it is in industry. Custom stencils are available for $150 from PCB Express or Stencils Unlimited, but this cost can be avoided by purchasing solder paste in a syringe (syringes of lead-free or conventional solder paste are available from Stencils Unlimited, see the list of resources at the end of the paper) for hand application. This works quite well for all but the most challenging applications, very fine-pitch packages such as ball-grid arrays or quad flat packs. For these, "package stencils" or "rework stencils" are available from Mini Micro Stencil Inc. There is no need for automated "pick and place" systems to mount the parts, this can be done using tweezers for all but the smallest parts. 0805 size resistors and capacitors are easy to place this way, 0402's are slightly more difficult, 0201's are very difficult.

The board or boards are then placed in the modified toaster oven, which is heated to approximately 20 degrees C above the specified melting temperature of the solder paste, kept at that temperature for about 1 minute, and then cooled by turning off the oven and opening the door. If lead free solder paste is used, which melts at 246 C, it may be necessary to bypass the toaster oven's thermostat. In any case, the thermostat setting should not be trusted. The temperature should be monitored using a type K thermocouple (cheap and readily available) inside the oven, connected to a simple thermocouple amplifier such as the Analog Devices AD595. A DMM can be used as a readout for manual control, or a microcontroller and relay can be used as an temperature controller.

Experiments show this technique to work very well. Applying solder paste by syringe to the pads of a 68-pin PLCC footprint was quite easy, and placing parts (except for the 0201 size resistors and capacitors) was also easy. Good solder joints with no bridges were obtained in all cases.

VI. Conclusion

Although the traditional path which led technically-inclined teenagers into careers in electronic engineering and technology, amateur radio and tinkering with electronics during the high school years, followed by a university education in engineering or technology, has nearly disappeared, it can be restored. Students must be given opportunities to participate in interesting and entertaining construction projects, and a support system must be of like-minded students must be developed. Instructors and more advanced students must be willing and able to offer advice and regarding design and construction techniques. Amateur radio projects and demonstrations of amateur radio can be an important and useful way to do this.

Resources

Here is a list of useful resources for those who are interested in incorporating similar projects into their courses:

The American Radio Relay League Inc. (ARRL), the national association for Amateur Radio (www.arrl.org): Lots of information about amateur radio and electronic construction techniques. Publisher of QST and QEX magazines. Many useful articles are available online (to members) and describe potential student projects. In particular, look at http://www.arrl.org/tis/info/HTML/Hands-On-Radio/ and http://www.arrl.org/tis/tismenu.html

Circuit Cellar (www.circuitcellar.com): Publisher of Circuit Cellar magazine. Lots of information on electronic construction projects and techniques, including use of a toaster oven for reflow soldering

The American QRP Club (www.AMQRP.org): a source of information on the SoftRock40, as well as other construction projects with emphasis on low-power and portable amateur radio equipment.

T-Tech Inc. (www.t-tech.com): Manufacturer of CNC milling machines for prototype PCB fabrication.

LPKF Laser and Electronics (www.lpkf.com): another manufacturer of CNC milling machines

Stencils Unlimited (www.stencilsunlimited.com): Solder paste, laser-cut prototype stencils for solder paste application, and information on using a toaster oven for reflow soldering.

PCB Express (www.pcbexpress.com): Prototype PCBs (including multilayer) and prototype stencils. Will provide up to $350 per year of PCBs per year to non-profit educational institutions. Interesting links to other information sources

Think & Tinker (www.thinktink.com): PCB prototyping equipment and information. Inexpensive tools for CNC milling machines.

Homebrew_PCBs (http://groups.yahoo.com/group/Homebrew_PCBs/): An internet group dedicated to "Designing, making, etching, soldering, printed circuit boards yourself".

Mouser Electronics (www.mouser.com): An electronic distributor with a very large selection of parts, excellent customer services, and favorable terms for small orders.

Jameco Electronics (www.jameco.com): Another distributor, catering to the hobbyist. Selection and prices are not as good as Mouser, but still worth a look.

Digikey (www.digikey.com) Still another distributor. If Mouser doesn't have it, Digikey might, and vice-versa. Terms for small orders are not quite as good as mouser.

Mini Micro Stencil Inc. (www.minimicrostencil.com) Flip-up rework stencils (http://www.minimicrostencil.com/flip-up_stencils.htm).

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