

## IETTI-106 – Advanced Electronics Projects (Semester 4 PROJECTS)

NAME: \_\_\_\_\_

Last update 1 August 2022

Duration	Project	Score
All semester	Career preparation <i>or</i> Certification exam	
First 6 weeks	Personal project (embedded system-based)	
Last 9 weeks	External client solution (embedded system-based)	

### Essential information about this course:

- Learning to independently manage projects and solve all the problems encountered in a project from conception to completion is even more important than learning how circuits work. You must budget your time and resources effectively to complete projects on time and to specification. Careful planning at the start of every project is key to success. Your instructor will offer advice on project selection and scope, and you will be responsible at the end for meeting the planned objectives.
- This is a laboratory course, but *the projects are not pre-designed*. You will manage each project just like real projects within your career.
- Your course grade is a simple average of all project grades, in turn based on timely and correct completion of all “deliverables”. As usual, clarifying questions are welcome, but all results presented to the instructor will be assessed just like answers submitted on an exam.
- You should budget a minimum of 12 hours per week for this course, approximately 8 hours in-class and 4 hours out-of-class. The lab is yours to use during all open-school hours. *Do not let the lack of fixed hours for this course lead to procrastination – manage your time wisely!*
- Successful students (1) review relevant theory before planning projects, (2) prioritize hands-on lab time, (3) set reasonable project goals, and (4) document data neatly and accurately.

## Values

This educational program exists for one purpose: to empower you with a comprehensive set of knowledge, skills, and habits to unlock opportunities in your chosen profession. The following values articulate personal attitudes guaranteed to fulfill this purpose, and the principles upon which this program is designed. They embody what I like to call a *strong learning ethic*, similar to a strong work ethic but applied to the learning process rather than a job.

**Ownership** – you are the sole proprietor of your education, of your career, and to a great extent your quality of life. No one can force you to learn, make you have a great career, or grant you a fulfilling life – these accomplishments are possible only when you accept responsibility for them.

**Responsibility** – *ensuring* the desired outcome, not just *attempting* to achieve the outcome. Responsibility is how we secure rights and privileges.

**Initiative** – independently recognizing needs and taking responsibility to meet them.

**Integrity** – living in a consistently principled manner, communicating clearly and honestly, applying your best effort, and never trying to advance at the expense of others. Integrity is the key to trust, and trust is the glue that binds all relationships personal, professional, and societal.

**Perspective** – prioritizing your attention and actions to the things we will all care about for years to come. Never letting short-term concerns eclipse the long-term.

**Humility** – no one is perfect, and there is always something new to learn. Making mistakes is a symptom of living, and for this reason we need to be gracious to ourselves and to others.

**Safety** – assessing hazards and avoiding unnecessary risk to yourself and to others.

**Competence** – your ability to consistently and independently apply knowledge and skill to the solution of practical problems. Competence includes the ability to verify the appropriateness of your solutions and the ability to communicate so that others understand how and why your solutions work.

**Diligence** – exercising self-discipline and persistence in learning, accepting the fact there is no easy way to absorb complex knowledge, master new skills, or overcome limiting habits. Diligence in work means the job is not done until it is done *correctly*: all objectives achieved, all documentation complete, and all root-causes of problems identified and corrected.

**Community** – your actions impact other peoples' lives, for good or for ill. Conduct yourself not just for your own interests, but also for the best interests of those whose lives you affect.

**Respect** is the acknowledgment of others' intrinsic capabilities, responsibilities, and worth. Everyone has something valuable to contribute, and everyone deserves to fully *own* their lives.

## EET Program Learning Outcomes

- (1) **COMMUNICATION and TEAMWORK** – Accurately communicate ideas across a variety of media (oral, written, graphical) to both technical and non-technical audiences; Function effectively as a member of a technical team.
- (2) **SELF-MANAGEMENT** – Arrive on time and prepared; Work diligently until the job is done; Budget resources appropriately to achieve objectives.
- (3) **SAFE WORK HABITS** – Comply with relevant national, state, local, and college safety regulations when designing, prototyping, building, and testing systems.
- (4) **ANALYSIS and DIAGNOSIS** – Select and apply appropriate principles and techniques for both qualitative and quantitative circuit analysis; Devise and execute appropriate tests to evaluate electronic system performance; Identify root causes of electronic system malfunctions.
- (5) **PROBLEM-SOLVING** – Devise and implement solutions for technical problems appropriate to the discipline.
- (6) **DOCUMENTATION** – Interpret and create technical documents (e.g. electronic schematic diagrams, block diagrams, graphs, reports) relevant to the discipline.
- (7) **INDEPENDENT LEARNING** – Select and research information sources to learn new principles, technologies, and/or techniques.

## Course description

This course reinforces the content of IETTI-223 (Advanced Electronics Theory) through multiple student-designed projects, each project's scope and functional criteria defined by the instructor with input from the student. In cases where the project is built for an external client, feedback from the client helps determine the project grade. This course also prepares the student for entry into the profession through résumé and cover letter writing as well as job research. All students must present their job research findings at the Technical Advisory Committee (TAC) meeting held with industry advisors. Additionally, students take a comprehensive exam covering all theory course topics to date.

## Course learning outcomes

- Set and meet deadlines for the timely completion of all project phases. (Addresses Program Learning Outcomes 1, 2)
- Test and modify prototype designs, researching appropriate information sources as necessary to assist in the design process. (Addresses Program Learning Outcomes 3, 4, 5, 7)
- Devise and safely implement conformance (type) tests based on criteria defined by the instructor and established technical standards, including but not limited to electrical safety (e.g. NFPA 79 Protective Bonding). (Addresses Program Learning Outcomes 3, 4, 6)
- Devise and safely implement functional tests based on practical project criteria defined by the instructor and/or external clients. (Addresses Program Learning Outcomes 3, 4, 6)
- Document all project work in written form including test results and schematic diagrams, and summary of lessons learned. (Addresses Program Learning Outcomes 1, 6)
- Demonstrate knowledge of Theory topics from IETTI-101, 104, 222, and 223 by taking a comprehensive written exam; or take an exam for an industry-recognized certification. (Addresses Program Learning Outcomes 4, 5)

## Required Tools, Supplies, and Software

Listed by IETTI course number and course type (**Thy** = theory, **Exp** = Experiments, **Prj** = Projects).

Semester 1 = IETTI-101 (Theory), 103 (Experiments), and 102 (Projects)

Semester 2 = IETTI-104 (Theory), 112 (Experiments), and 105 (Projects)

Semester 3 = IETTI-222 (Theory), 221 (Experiments), and 220 (Projects)

Semester 4 = IETTI-223 (Theory), 225 (Experiments), and 106 (Projects)

<b>Tool, Supply, or Software installation</b>	Thy 101	Exp 103	Prj 102	Thy 104	Exp 112	Prj 105	Thy 222	Exp 221	Prj 220	Thy 223	Exp 225	Prj 106
\$25 scientific calculator	X	X	X	X	X	X	X	X	X	X	X	X
\$300 personal computer	X	X	X	X	X	X	X	X	X	X	X	X
\$10 USB “flash” drive	X	X	X	X	X	X	X	X	X	X	X	X
\$50-\$400 digital multimeter		X	X		X	X		X	X		X	X
\$150 USB-based oscilloscope		X	X		X	X		X	X		X	X
\$10 solderless breadboard (e.g. Busboard BB830)		X	X		X	X		X	X		X	X
\$25 grounding wrist strap		X	X		X	X		X	X		X	X
\$10 slotted screwdrivers (1/8”,1/4”)		X	X		X	X		X	X		X	X
\$10 Phillips screwdrivers (#1,#2)		X	X		X	X		X	X		X	X
\$10 jeweler’s screwdriver set		X	X		X	X		X	X		X	X
\$10 wire strippers, 18-24 AWG		X	X		X	X		X	X		X	X
\$10 needle-nose pliers		X	X		X	X		X	X		X	X
\$20 diagonal wire cutters		X	X		X	X		X	X		X	X
\$10 metal rule (inches & mm)		X	X		X	X		X	X		X	X
\$10 alligator-clip jumper wires (package of at least ten)		X	X		X	X		X	X		X	X
\$15 batteries: 6 Volt and 9 Volt		X	X		X	X		X	X		X	X
\$15 illuminated jeweler’s loupe		X	X		X	X		X	X		X	X
\$10 safety glasses			X		X	X			X			X
\$25-\$100 soldering iron (pencil-tip), 30 Watts or less			X		X	X			X			X
\$15 tube/spool of rosin-core solder			X		X	X			X			X
\$200 PLC and software		X			X			X			X	
\$15 microcontroller and software								X			X	X
\$0 software: schematic editor		X	X		X	X		X	X		X	X
\$0 software: Notepad++ text editor		X			X			X			X	
\$0 software: NGSPICE circuit sim.		X			X			X			X	
\$0 software: WSL		X			X			X			X	
\$0 software: tshoot fault sim.		X			X			X			X	
\$0 software: PCB layout editor											X	X
\$0 software: packet-sniffing software										X	X	X

## Required Tools, Supplies, and Software

**Scientific calculator** – at minimum your calculator must perform trigonometric functions (sine, cosine, tangent, etc.), offer multiple memory registers, and display values in both scientific and “engineering” notations. I recommend the Texas Instruments model TI-36X Pro because it easily performs complex-number arithmetic necessary for AC circuit analysis and is inexpensive.

**Personal computer** – all course materials are available in electronic format and are free (most are also open-source), making a portable computer extremely useful. The school provides personal computers for on-campus use, but having your own will enable you to work outside of school. Most operating systems, size of hard drive, amount of RAM memory, and screen size is appropriate, but your computer must have a keyboard and mouse (i.e. no tablets). Avoid ChromeBooks. Useful features worth higher cost include an RJ-45 Ethernet port and an EIA/TIA-232 (9-pin) serial port.

**Multimeter** – this is your first and most important electronic test instrument. At minimum it must measure DC and AC voltage, DC and AC current (milliAmpere range), resistance, and “diode check” voltage drop. Useful features worth higher cost include microAmpere current measurement, true-RMS AC measurement (for second-semester courses and above), frequency measurement, capacitance measurement, and minimum/maximum value capture. Cost is a strong function of accuracy, frequency range, and safety (“Category” ratings for over-voltage exposure). The Fluke model 87-V is an excellent professional-grade choice for digital multimeters, and the Simpson 260 is an excellent professional-grade choice for analog multimeters. Note that Fluke offers a 25% educational discount for students.

**Oscilloscope** – once too expensive for student purchase, entry-level USB-based oscilloscopes now cost less than a textbook. Pico Technology is an excellent brand, and their model 2204A comes with high-quality probes as well. Plugged into your personal computer using a USB cable, the Picoscope turns your computer’s monitor into a high-resolution oscilloscope display. Features include two measurement channels, 10 MHz bandwidth, built-in arbitrary waveform generator (AWG),  $\pm 100$  Volt over-voltage protection, digital “cursors” for precise interpretation of amplitude and frequency, meter-style measurement capability, Fast Fourier Transform algorithm for frequency-domain measurement, export ability to several graphic image formats as well as comma-separated variable (.csv) files, and serial communications signal decoding. Together with your multimeter, solderless breadboard and Development Board (which you will construct in the IETTI-102 Project course and is yours to keep) this forms a complete electronics laboratory for doing experiments and projects outside of school.

**Soldering** – the equipment you purchase for soldering need not be expensive, *if* you purchase the right solder. For electronics work you *must* use rosin-core solder. Kester is an excellent brand, and you should avoid cheap imported solders. For lead-based solder, a 63% tin and 37% lead alloy (Sn63/Pb37) works very well. A one-pound roll is likely more solder than you will need in these courses, so I recommend buying just a small tube or small roll. I recommend a fine-tipped soldering iron (15 Watts continuous power, although some with adjustable temperature controls may have higher power ratings to get up to soldering temperature more quickly) and a solder diameter 0.031 inches or smaller for doing fine printed-circuit board work. Also, keep the tip of your soldering iron clean by wiping it against a damp sponge or paper towel when hot, and not leaving it hot any longer than necessary. Hakko, X-tronic, and Lonove are all recommended brands.

**PLC** – these courses are not brand- or model-specific, but the Koyo “CLICK” series of Programmable Logic Controller sold by Automation Direct is highly recommended for low cost and ease of use.

**Microcontroller** – these courses are not brand- or model-specific, but the Texas Instruments MSP430 series is highly recommended for their powerful features, modern design, and programmability in multiple languages (assembly, C, C++, and Sketch). I particularly recommend the model MSP-EXP430G2ET “LaunchPad” development board (MSP430G2553IN20 microcontroller chip) with Code Composer Studio for the IDE software. A hobbyist-grade microcontroller such as the popular Arduino and Parallax BASIC Stamp are permissible only in first-year courses, but not in second-year courses.

## Required Tools, Supplies, and Software

All software required for these courses is free, and some of it is open-source.

**Schematic editor** – this is used to draft schematic diagrams for circuits. A good one is **TinyCAD**, but there are also web-based CAD tools such as **circuitlab.com** and **diagrams.net** that are very effective and easy to use. **KiCad** offers an excellent schematic editor as well as other tools useful for translating schematic diagrams into printed circuit board (PCB) layouts, useful in later courses.

**Text editor** – this is used to create plain-text files, kind of like a word processor but lacking formatting features such as typeface, font size, etc. It is absolutely necessary for writing code of any kind. **Notepad++** is a very good editor, but others work well too.

**NGSPICE** – this is a modern adaptation of the venerable SPICE circuit simulator which uses a text-coded “netlist” rather than a visual schematic diagram to describe circuits. Very powerful, and with decades of netlist examples from earlier versions of SPICE to use as references. The installer lacks sophistication, being nothing more than a compressed (zip) file that you unpack. Once installed, you should instruct your computer’s operating system to automatically associate any files ending in the extension **.cir** with the NGSPICE executable file **ngspice.exe** so that all of your netlist files will appear with the NGSPICE icon and will automatically load into NGSPICE when double-clicked.

**WSL** – Windows Subsystem for Linux is a “virtual machine” Linux operating system that runs within the Windows operating system, giving you a command-line user environment mimicking that of a Unix operating system. It is a free application from Microsoft, with instructions available from Microsoft on how to install. I recommend installing the “Debian” distribution of WSL. Once installed, you will issue these commands in the following order to install all the necessary programming tools:

- `sudo apt update`
- `sudo apt install build-essential`

**tshoot** – this is a specialized circuit-simulator program that inserts faults into circuits and tests your ability to locate them. The download consists of a single “tar” archive file which you must unpack and compile using the following two commands within a Unix-type operating system or within WSL. The fourth command listed below starts and runs the application:

- `mkdir tshoot ; mv -v *.tar tshoot ; cd tshoot`
- `tar xvf *.tar`
- `make`
- `./tshoot`

**IDE software** – an “Integrated Development Environment” is a software package used to write code, and for our purposes this would be code meant to run in a microcontroller. For the Texas Instruments MSP430 series, the main IDE is called **Code Composer Studio**, and it supports programming in assembly language, C, and C++. A third-party add-on to Code Composer Studio called **Energia** supports programming in the Sketch language, identical to that used by the popular Arduino microcontroller series.

**PCB layout editor** – this is specialized drafting software intended for creating graphic files to be sent to printed circuit board (PCB) manufacturers so you can order your own custom PCBs. **PCB Artist** is free and exceptionally easy to use, but only exports files to the manufacturer Advanced Circuits. Free PCB layout editors capable of exporting “Gerber” format files which are universally accepted by PCB manufacturers include **EasyEDA**, **KiCad**, and **pcb**. Of these I recommend **EasyEDA** for beginners, or **PCB Artist** if you don’t mind being locked into one manufacturing option.

**Packet-sniffing software** – this is specialized software for monitoring network communications. An excellent (and free) option is **Wireshark**.

[file eet\\_tools](#)

## Grading standards for Project courses

Your grade for this course is based on the simple average of all project scores (rounded *down* to a whole-number value). Each individual project score originates from the rubric included within each listed project.

This course is based on project design, testing, and construction, and does not have fixed start and stop times as is the case with instructor-facilitated theory sessions. However, your punctual and consistent attendance is important for your success, as these activities require significant time-on-task to complete. Any off-campus project work must be arranged with the instructor and teammates.

If you must be late or absent, it is imperative that you contact your instructor and all teammates so plans may be adjusted. It is still your responsibility to meet all deadlines.

A failing (F) grade will be earned for the entire course if any project is not completed on or before the deadline date, or for any of the following behaviors: false testimony (lying), cheating on any assignment or assessment, plagiarism (presenting another's work as your own), willful violation of a safety policy, theft, harassment, sabotage, destruction of property, or intoxication. These behaviors are grounds for immediate termination in this career, and as such will not be tolerated here.



## Getting help in the lab

Success in this career is largely a function of your ability to independently solve complex problems. You will find that the design, construction, testing, and diagnosis of systems for experiments and projects are prime opportunities to hone this skill. Many times you will find yourself faced with a problem that you do not think you can solve. Your instructor's job is to provide practical strategies and techniques you can use to solve the problem, without directly solving the problem for you. Although this may feel frustrating because the instructor is withholding a solution from you, know that if the instructor were to solve the problem for you it would actually hinder your own development.

Any time you call for help to diagnose a problem, your instructor will first check to see you have done the following:

- **Simplify** – make problems manageable by building and testing your system in stages, by dividing large systems into smaller sections to isolate problems, and by avoiding complexity that isn't absolutely necessary to the function you are trying to obtain at that time. A common mistake is to build large systems without testing along the way in an attempt to save time, but this strategy almost never works!
- **Document** – draw a diagram before building any system, and use this to guide your analysis and design decisions. Also, have any other relevant documents available for reference, such as datasheets, tutorials, etc. A common mistake is to build systems without first building up this documentation, again in a futile effort to save time.
- **Measure and record** – take measurements using appropriate test equipment, because these measurements will reveal what your senses alone cannot perceive. Record those test results so you will not have to rely on memory to recall what you did.
- **Foundational Concepts** – always apply Foundational Concepts such as the guaranteed effects of opens and shorts, Ohm's Law, Joule's Law, Conservation of Energy and of Electric Charge, Kirchhoff's Laws, properties of series and of parallel networks, etc. when solving problems. Reference a list of these if necessary, checking them one by one to stimulate and guide your reasoning.

A good way to remember these is to use the phrase, "*Slow Down My Friend!*" (Simplify, Document, Measure/record, and Foundational Concepts) which is also a reminder that problem-solving requires patience. A great many student problems are caused by impatience and an urge to take shortcuts!

**PROJECT:** Career Preparation

This aim of this project is to give you perspective on the career field and also prepare you for job applications and interviewing. No previous submissions will be granted credit. For singular documents such as a résumé, your submission must be an improvement over all previous versions. Any instance of plagiarism will result in a failing grade for the entire course.

Credit for each “deliverable” is all-or-nothing. It is recommended you submit these well ahead of the deadline in order to give your instructor time to review as well as give yourself time to correct any errors. No penalty is levied for errors, but the grade for each is final by the deadline date.

**Source text** – *Career Guide* learning module

**URL** – [http://ibiblio.org/kuphaldt/socratic/model/mod\\_career.pdf](http://ibiblio.org/kuphaldt/socratic/model/mod_career.pdf)

Project Deliverables include the following:

- **Written summary of attributes sought by employers** as gleaned from *multiple* advertised descriptions of electronics or related-skill technician jobs, including knowledge, skills, credentials, professional habits, and values. Job descriptions are easily found at job-search websites (e.g. [indeed.com](http://indeed.com)) as well as from the “Careers” pages of employer websites. The sampled job descriptions must come from more than one employer, and must be included in their entirety as source material with your submitted summary, to be presented as a collection of digital documents to this semester’s Technical Advisory Committee (TAC) meeting as useful guidance for program faculty. The employers sampled for your knowledge/skill/habit summary must *not* be personally represented at the upcoming TAC meeting.
- **Participation in Technical Advisory Committee (TAC) meeting** held once per semester. This committee brings industry representatives together with faculty and students to offer advice on how to best run the program. Your task in this meeting is to present your findings on attributes sought by employers of electronics technicians, to give the meeting broader perspective. You should expect to be asked questions by the employer representatives as well, regarding your choice of careers, projects you are working on, etc.
- Update your **résumé** and optimize it for a current electronics technician job description, including a copy of this job description for reference.
- Write a **cover letter** directed to the appropriate individual for the same job description used to optimize your résumé.
- Take a **certification prep exam** covering topics from all prior and current theory courses.

**PROJECT:** Career Preparation      **NAME:** \_\_\_\_\_

Semester calendar URL – <http://ibiblio.org/kuphaldt/socratic/model/calendar.html>

*Instructor certifies each deliverable's completion by the prescribed deadline for credit.* Note: "TAC" means the *Technical Advisory Committee* for the Electronics Engineering Technology program.

<b>Deliverables</b>	<b>Deadline</b> (by 4:00 PM)
<input type="radio"/> Explain to instructor how this project will be graded <input type="radio"/> Submit an official electronics technician job description <input type="radio"/> Submit another official electronics technician job description <input type="radio"/> <i>Neither</i> job description from an employer on our TAC	Day 8 of semester (–5% per day if late)
<input type="radio"/> Submit written summary of attributes sought by employers <input type="radio"/> Attach job description(s) informing your summary <input checked="" type="radio"/> Employer(s) <i>not</i> represented on our TAC	Day 15 of semester (–5% per day if late)
<input type="radio"/> Submit rough draft of résumé in PDF format <input type="radio"/> Submit rough draft of cover letter in PDF format <input type="radio"/> Attach job description targeted by résumé and cover letter	Day 30 of semester (–5% per day if late)
<input type="radio"/> Share results of certification prep exam (practice version) self-graded with answers provided and score unrecorded	Day 40 of semester (–5% per day if late)
<input type="radio"/> Submit cover letter in PDF format with no errors <input type="radio"/> Attach job description targeted by letter	Day 50 of semester (–5% per day if late)
<input type="radio"/> Submit résumé in PDF format with no errors <input type="radio"/> Attach job description targeted by résumé	Day 60 of semester (–5% per day if late)
<input type="radio"/> Present written summary of attributes sought by employers to all participants at the TAC meeting	TAC meeting day (worth 10%)
<input type="radio"/> Certification prep exam score <input checked="" type="radio"/> (covers topics from all prior and current theory courses)	Last day of semester (worth 90%)

**PROJECT:** Career Preparation

**TAC committee employer list**

*Note: your sampled job descriptions must exclude all employers on the following list, because these employers already participate on our Technical Advisory Committee (TAC) and as such you will already be receiving direct advice from them:*

- Schweitzer Engineering Laboratories
- Avista Utilities
- Meter Group
- On Semi
- Raute-Metriguard
- Washington Alarm

## **PROJECT: Certification Exam**

This aim of this project is to obtain a technical certification from a recognized body unassociated with the college. You will identify an appropriate certification, obtain the necessary preparatory materials, study and practice for the exam, and then take the exam itself.

Your score on the official certification exam will be your score for this project. If the examining organization does not reveal individual scores, your score will be computed based on the percentage of exam sections passed. Deliverables completed after their respective deadlines or not completed at all will result in penalties.

Recommended certification bodies include the following:

- IPC International
  - IPC-A-610 soldering certification
  - IPC J-STD-001 soldering certification
  
- ISCET (International Society of Certified Electronics Technicians)
  - Associate-level CET exam
  - Electronic Systems Associate (ESA) exams – the CET broken into four separate exams
  
- FCC (Federal Communications Commission)
  - Amateur radio “Technician” license
  - Amateur radio “General” license
  - Amateur radio “Amateur Extra” license
  - General Radio Operator’s license
  
- ETA International (Electronic Technician Association)
  - Associate Certified Electronics Technician (CETa)
  - Electronics Modules (EM1-5) – the CETa broken into five separate exams
  - Student Electronics Technician

PROJECT: Certification Exam      NAME: \_\_\_\_\_

Semester calendar URL – <http://ibiblio.org/kuphaldt/socratic/model/calendar.html>

*Instructor certifies each deliverable's completion by the prescribed deadline for credit.*

<b>Deliverables</b>	<b>Deadline (by 4:00 PM)</b>
<input type="radio"/> Explain to instructor how this project will be graded <input type="radio"/> Identify a suitable certification to obtain <input type="radio"/> Determine cost and testing center location(s)	Day 8 of semester (–5% if late)
<input type="radio"/> Order/request preparatory materials	Day 12 of semester (–5% if late)
<input type="radio"/> Register to take the certification exam <input type="radio"/> Show confirmed date and cost of exam	Day 18 of semester (–10% if late)
<input type="radio"/> Submit practice exam results <input type="radio"/> Submit self-assessment on results – strengths and weaknesses	Day 40 of semester (–10% if late)
<input type="radio"/> Certification exam score = _____	

**PROJECT:** Personal (embedded system-based)

For this project you will design, prototype, test, construct, and document a system for personal or school use, incorporating embedded system (e.g. programmable computer) technology. A campus-based project is eligible for school funding since it will remain the property of the school.

This will be an *individual* project unless it is of sufficient complexity to warrant a team effort. If done as a team, all members will draft and sign a contract specifying (at minimum) the individual responsibilities of each member (e.g. who has ownership of which deliverables), the best means to contact each member, and specific grading standards for poor individual performance compromising the team effort. Teams comprised of students in different program semesters are welcome, so long as each team member's deliverables address the learning objectives of their project course. Any project selected must meet with the instructor's approval for relevance and complexity, and the instructor also reserves the right to assign a project if it meets a known need. Pre-engineered kits are not allowed unless you make substantial modifications to the design.

Suggested project ideas include:

- Single-board microprocessor-based computer (e.g. Z80, 6502)
- Electronic test equipment (e.g. oscilloscope, DMM)
- Programmable power supply
- Alarm clock with a variety of outputs (e.g. audible, visual, haptic)
- Cyclocomputer or other athletic performance monitor
- Digital communication network (wired or wireless)
- Chemical analyzer (e.g. carbon dioxide gas monitor)
- Remote-control vehicle
- Solar-powered weather monitoring station
- Robot
- Assistive technology device (e.g. aid to the blind or deaf)
- Closed-loop control system for some simple process (e.g. soldering iron temperature control)

**PROJECT:** Personal (embedded system-based)

Semester calendar URL – <http://ibiblio.org/kuphaldt/socratic/model/calendar.html>

*Instructor certifies each deliverable's completion by the prescribed deadline for credit. Every test must either be directly witnessed by the instructor or photo/video-recorded, and may be repeated as necessary.*

Deliverables	Deadline (by 4:00 PM)
<ul style="list-style-type: none"> <li><input type="radio"/> Project selected</li> <li><input type="radio"/> Explain to instructor how this project will be graded</li> <li><input type="radio"/> Submit Conformance criteria (e.g. safety, reliability) for each stage (refer to “Construction Standards” pages)</li> <li><input type="radio"/> Submit Functional criteria (e.g. features) for each stage</li> <li><input type="radio"/> Divide project work into manageable stages and set deadlines</li> <li><input type="radio"/> Submit prototype design (e.g. rough-draft schematic)</li> <li><input type="radio"/> Locate/order components, materials, and other supplies</li> <li><input type="radio"/> [Team project only] Write, sign, and submit Team Contract</li> </ul>	<p>All-lab day 1 (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> </ul>	<p>All-lab day 2 (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> </ul>	<p>All-lab day 3 (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/> Prototype Conformance Test results recorded</li> <li><input type="radio"/> Prototype Functional Test results recorded</li> </ul>	<p>All-lab day 4 (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/> Final assembly and inspection</li> <li><input type="radio"/> Finished project Conformance Test(s)</li> <li><input type="radio"/> Finished project Functional Test(s)</li> <li><input type="radio"/> Submit written Conformance and Functional Test report showing results from both prototype and finished testing</li> </ul>	<p>All-lab day 5 (–5% per re-work) (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/> Submit written “Lessons learned” report</li> <li><input type="radio"/> Schematic diagram challenge (final version)</li> <li><input type="radio"/> Additional objectives (see “Project Grading” page)</li> </ul>	<p>All-lab day 6 (–5% per re-work) (–5% per day if late)</p>



## Project grading

The standard for projects is mastery of skill and technique, and you will be given ample time to practice until everything is correct. You are also free to ask questions at any time if you need help, but know that the instructor's responsibility is to offer advice rather than solve problems for you. In this career your value is a function of your ability to solve complex problems on your own, and the *only* way to build this skill is by solving simpler problems on your own!

When you submit your finished work to the instructor the expectation is that you have thoroughly checked and double-checked it all for correctness. If any portion of your submitted work fails to meet a standard, you will be required to re-do that work and a  $-5\%$  penalty will be levied against your project score. Timely completion of all deliverables is important as well. Missed deadlines will result in a  $-5\%$  penalty per school day. If working as a team, these penalties apply equally to all team members. Your over-all project score will be capped at a maximum value of 50% if the project is not fully functional by the final due date.

The "schematic diagram challenge" deserves elaboration here. Sketching a complete and accurate schematic diagram is vitally important for every system you design and build, but it takes too long for the instructor to perform a wire-by-wire inspection of every student's diagram on every system built. Instead, the instructor tests the accuracy of your schematic diagram by selecting random portions of your system and having you predict and measure signals there. These could be individual components or test points, they could be assuming normal operation or some special condition (e.g. a simulated fault), they could be selected from the physical system with you having to reference the schematic diagram, or vice-versa. In all cases, you must show an accurate correspondence between what you have built and what you have drawn, and demonstrate a thorough understanding of your system's behavior. Preparation consists of thoroughly reviewing both your system and your diagram, predicting what kinds of signals you ought to measure at all points in your system and making absolutely sure your schematic diagram is complete and accurate.

Correctly completing all deliverables by their respective deadlines contributes 75% to your over-all project score. Additional points are available for completing the following by the last All-lab due date listed in the Deliverables table:

- +5% – Final documentation created on computer, not hand-written (including schematic diagrams).
- +5% – Write an "Abstract" explaining to a non-expert in very simple, non-technical terms what the project is supposed to do.
- +5% – *Bill of Materials* complete with part numbers, manufacturers, and current list prices for *all* components (including recycled components), plus a total cost for the project.
- +5% – Produce a "User's Guide" explaining to a non-expert how to operate the project. This may take the form of a written document or an instructional video.
- +5% – Impeccable craftsmanship, comparable to that of a professional assembly. This includes all conductors neatly routed either parallel or perpendicular to each other.

**PROJECT:** External client solution (embedded system-based)

For this project you will design, prototype, test, construct, and document a project incorporating embedded system (i.e. programmable computer) technology for an external client. Since this is a system built for a client, expenses should be covered by that client unless negotiated otherwise. Projects built for and funded by the college are permitted, provided someone outside of the EET program serves as the external client (e.g. a technician or engineer volunteering from a private company, a staffperson or other faculty member at the college). Any project selected must meet with the instructor's approval for relevance and complexity, and the instructor also reserves the right to assign a project if it meets a known need.

This will be an *individual* project unless it is of sufficient complexity to warrant a team effort. If done as a team, all members will draft and sign a contract specifying (at minimum) the individual responsibilities of each member (e.g. who has ownership of which deliverables), the best means to contact each member, and specific grading standards for poor individual performance compromising the team effort. Teams comprised of students in different program semesters are welcome, so long as each team member's deliverables address the learning objectives of their project course. Pre-engineered kits are not allowed unless you make substantial modifications to the design.

Examples of external clients include, but are not limited to, the following:

- Faculty from other departments on campus (e.g. natural sciences, life sciences, engineering)
- Staff and operational departments on campus (e.g. physical plant, recruiting, marketing)
- Faculty from other colleges
- Faculty from high schools
- Community organizations
- Businesses, both small and large
- Cities and governmental organizations
- Museums, libraries, and para-educational organizations
- Law enforcement

Suggested project ideas include:

- Educational or promotional game
- Demonstration system useful for educating tour attendees about the EET program or about Electronics in general
- Data acquisition system useful for scientific research
- Monitoring system for automobile or human traffic
- Chemical analyzer (e.g. carbon dioxide gas monitor)
- Digital communication network (wired or wireless)
- Assistive technology device (e.g. aid to the blind or deaf)
- Wearable computer system (microcontroller or single-board computer based; e.g. Raspberry Pi)

**PROJECT:** External client solution (embedded system-based)

Semester calendar URL – <http://ibiblio.org/kuphaldt/socratic/model/calendar.html>

*Instructor certifies each deliverable's completion by the prescribed deadline for credit. Every test must either be directly witnessed by the instructor or photo/video-recorded, and may be repeated as necessary.*

Deliverables	Deadline (by 4:00 PM)
<ul style="list-style-type: none"> <li><input type="radio"/> Project and client selected</li> <li><input type="radio"/> Explain to instructor how this project will be graded</li> <li><input type="radio"/> Identify funding sources and budgetary constraints</li> </ul>	<p style="text-align: center;">All-lab day 7 (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/> Submit Conformance criteria (e.g. safety, reliability) for each stage (refer to “Construction Standards” pages)</li> <li><input type="radio"/> Submit Functional criteria (e.g. features) for each stage</li> <li><input type="radio"/> Submit prototype design (e.g. rough-draft schematic)</li> <li><input type="radio"/> Locate/order components, materials, and other supplies</li> <li><input type="radio"/> Specify future deliverables and set deadlines</li> <li><input type="radio"/> [Team project only] Write, sign, and submit Team Contract</li> </ul>	<p style="text-align: center;">All-lab day 8 (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> </ul>	<p style="text-align: center;">All-lab day ____ (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> <li><input type="radio"/></li> </ul>	<p style="text-align: center;">All-lab day ____ (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/> Prototype Conformance Test results recorded</li> <li><input type="radio"/> Prototype Functional Test results recorded</li> </ul>	<p style="text-align: center;">All-lab day ____ (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/> Final assembly and inspection</li> <li><input type="radio"/> Finished project Conformance Test(s)</li> <li><input type="radio"/> Finished project functionality shown to instructor and client</li> <li><input type="radio"/> Submit written Conformance and Functional Test report showing results from both prototype and finished testing</li> </ul>	<p style="text-align: center;">All-lab day ____ (–5% per re-work) (–5% per day if late)</p>
<ul style="list-style-type: none"> <li><input type="radio"/> Submit written “Lessons learned” report</li> <li><input type="radio"/> Submit Bill of Materials and proof of remuneration</li> <li><input type="radio"/> Schematic diagram challenge (final version)</li> <li><input type="radio"/> Submit User’s Guide written for client</li> <li><input type="radio"/> Additional objectives (see “Project Grading” page)</li> </ul>	<p style="text-align: center;">Last all-lab day (–5% per re-work) (–5% per day if late)</p>

**PROJECT:** External client solution (embedded system-based)

**Project grading**

Timely completion of all deliverables is worth 75%. Missed deadlines result in a -5% penalty per school day. If working as a team, the late penalty applies equally to all team members. Project score will be capped at a maximum value of 50% if the project is not fully functional by the end of the semester. Additional points awarded for the following, if submitted by the last All-lab due date listed in the Deliverables table:

- **+15%** – Score given by client on a 0 to 15 scale where 7 is satisfactory and 15 is awesome.
- **+5%** – Final documentation created on computer, not hand-written (including schematic diagrams).
- **+5%** – Impeccable craftsmanship, comparable to that of a professional assembly. This includes all conductors neatly routed either parallel or perpendicular to each other.

## Functional and Conformance Testing

Engineering is the process of *designing to specification*. As such, every new design must begin with identifying those specifications and determining how to prove the design will meet or exceed each specification. Two different categories of tests apply to any design, *Functional Tests* and *Conformance Tests* (also known as *Compliance Tests* or *Type Tests*).

**Functional Tests** check whether the system fulfills its intended function(s). These tests focus on features, examples of which are listed here:

- A radio communication system’s ability to both transmit and receive certain types of information, to provide the user with relevant data on the system’s performance, etc.
- An engine’s ability to output a certain minimum amount of horsepower.
- A computer’s ability to process certain types of mathematical operations at certain minimum speeds, to execute functions unique to that design.
- A security system’s ability to identify authorized versus unauthorized personnel, to log access data.
- An electric motor’s ability to achieve an advertised energy conversion efficiency.
- A switch’s ability to open and close an electric circuit on demand.
- The display(s) and controls for an electronic system operate consistently and predictably.

**Conformance Tests** check whether the system complies with third-party regulations, safety standards, reliability requirements, etc.

- A radio communication system’s ability to transmit only the intended frequency(ies) and to not exceed FCC-regulated power output.
- An engine’s ability to operate while outputting no more pollutants than allowed by the EPA.
- A computer’s ability to process industry-standardized data types, to not radiate or conduct high-frequency signals that could interfere with other electronic devices.
- A security system’s reliability as measured over a specified range in time.
- An electric motor’s resistance to electrical ground faults, its ability to operate while not exceeding a maximum specified amount of acoustic noise.
- A switch’s physical dimensions agree with NEMA standards, can safely interrupt rated current, has a certain minimum dielectric strength, etc.
- The display(s) and controls for an installed system being operable by someone restricted to a wheelchair (i.e. Americans with Disabilities Act “Standards for Accessible Design”).

When selecting and designing your own project, you will be asked to generate a list of testable criteria which will become the foundation of your project’s Functional and Conformance Tests. After selecting your project concept, you will decide what it must do (Functional) and identify relevant safety, quality, reliability, and/or interference concerns (Conformance). Functional criteria are more or less arbitrary, but Conformance criteria is objectively-based.

The following pages list industry best-practice standards and recommendations with source references to external documents. If you are at a loss for Conformance criteria in your project, this is an excellent reference. A well-designed Conformance Test reliably measures its criterion, whatever that may be.

## Construction Standards

The following list contains best-practice standards applicable to most electrical and electronic projects:

### General layout

- All electrical components shall be located to avoid accidental exposure to liquids.
- All manual controls (e.g. buttons, handles, knobs) shall be accessible and function without undue effort.
- Fragile components (e.g. heat-sensitive semiconductors) shall be easily accessed for replacement.

### Fastening

- All threaded fasteners shall be properly engaged and tightened.
- A minimum of 1-1/2 threads shall extend beyond the threaded hardware (e.g., nut), unless otherwise specified otherwise.
- All cable ties shall be trimmed off, flush with the back end of the strap head. (*NASA-STD-8739.4, NFPA 79 2007 edition (13.1.5.6)*)

### Thermal considerations

- Power-handling components shall have adequate cooling capacity, usually in the form of a heat sink.
- When mounted vertically, the hottest components shall be located on top so their convected heat does not warm other components.
- Components dissipating heat in quantities of 1 Watt or greater, or in quantities sufficient to damage a PCB shall be mounted with sufficient standoff [ $> 1.5$  mm (0.060 in)] and shall be mechanically restrained.

### Power wiring

- All electrical sources greater than 30 Volts shall be overcurrent-protected and all related wire connections shall be guarded against accidental contact (e.g. use recessed terminals with no exposed metal).
- Overcurrent protection shall be on the ungrounded (“hot”) conductor(s) only (*NFPA 70 2017 edition (240.15(A))*). No grounded conductor shall be overcurrent-protected or switched (*NFPA 70 2017 edition (240.22)*).
- Small power transformers shall be overcurrent-protected on their primary windings, and optionally on their secondary windings. For primary currents less than 2 Amperes, exclusive primary overcurrent protection may be as high as 300% of full-load rating, 250% if secondary overcurrent protection also included. For secondary currents less than 9 Amperes, overcurrent protection may be as high as 167% of full-load rating. (*NFPA 70 2017 edition (450.3(B))*)
- All metallic panels and electrical enclosures receiving power from the AC line shall be bonded to earth ground for safety, and this bonding verified by electrical resistance measurement. Resistance between nearest facility ground point (e.g. plug ground prong) and chassis shall be 0.1  $\Omega$  or less. (*NASA-STD-4003A, NFPA 79 2007 edition (18.1)*)
- All power conductors shall be strain-relieved so that tension applied to them will not stress the electrical connections themselves (*NFPA 79 2007 edition (13.4.3.1.1)*). Permanent conductors not in a raceway shall be securely fastened at least every 6 inches using cable ties or other appropriate means.

- All conductors shall be prevented from chafing against any sharp edges (*NFPA 79 2007 edition (13.5.1.2)*).
- Proper use of colors for electrical power source wiring (e.g. red and black for DC + and −, black and white for AC “hot” and “neutral”, green for earth ground) (*NFPA 79 2007 edition (13.2)*). Colored tape is permissible at both ends of a wire whose insulation is not of the right color.

### Other wiring and connections

- Proper wire sizes and insulation ratings throughout (e.g. sufficient wire gauge for the expected current, insulation over-rated for the highest voltages expected) (*NFPA 79 2007 edition (12.5)*).
- Compression terminals – crimping of solid wire, component leads, or stranded wire that has been solder-tinned, is prohibited. The conductor shall extend a minimum of flush with, and a maximum of one (1) wire diameter beyond the conductor crimp edge. No protruding wire strands outside the terminal barrel. (*NASA-STD-8739.4*)
- No splices allowed between terminals (*NFPA 79 2007 edition (13.1.2.1)*).
- Only solid wires shall be wrapped around a screw terminal, and this shall be clockwise. Wrap distance shall be between  $180^\circ$  and  $270^\circ$  (between  $\frac{1}{2}$  and  $\frac{3}{4}$  turn).
- Attached wires shall withstand being lightly pulled with fingers.
- Wire insulation shall be intact (i.e. no bare wires anywhere).
- After insulation removal, the remaining conductor insulation shall not exhibit any damage such as nicks, cuts, or charring. Conductors with damaged insulation shall not be used. Scuffing from mechanical stripping or slight discoloration from thermal stripping is acceptable. (*NASA-STD-8739.3*)
- Panel wiring shall be neat in appearance.
- Multiple conductors extending beyond an enclosure or panel shall be bundled together as a multi-conductor cable wherever possible.
- No use of solderless breadboards on permanent assemblies; use only for prototyping.
- No use of tape as insulation; use heat-shrink tubing instead.
- Cables shall not be bent below the minimum recommended inside bend radius (6 diameters for flexible coaxial cable, 3 diameters for multi-wire harnesses 10 AWG and smaller). (*NASA-STD-8739.4*)

## Soldered connections

- Visual Appearance – the appearance of the solder joint surface shall be smooth, nonporous, undisturbed and shall have a finish that may vary from satin to bright depending on the type of solder used (*NASA-STD-8739.3*). Overheated solder has a dull, gray, frosty and/or crystallized appearance (*NASA-STD-8739.2*).
- Solder Coverage – the molten solder shall flow around the conductor and over the termination areas. (*NASA-STD-8739.3*)
- Tinning – tinned surfaces, which are to become part of the solder termination, shall exhibit 100% coverage. When tinning stranded wires, the solder shall completely wet the conductor, penetrate to the inner strands, and exhibit 100% coverage. Wire strands shall remain distinguishable. Wicking of flux or solder shall be minimized. (*NASA-STD-8739.3* and *NASA-STD-8739.4*)
- Minimum Insulation Clearance – the insulation shall not be embedded in the solder joint. The contour of the conductor shall not be obscured at the termination end of the insulation. (*NASA-STD-8739.3*)
- Maximum Insulation Clearance – the insulation clearance shall be less than two wire diameters, including insulation, but in no case shall permit shorting between adjacent conductors. Insulation clearance shall be referenced from the first point of contact of the conductor to the terminal. (*NASA-STD-8739.3*)
- Mechanical Support and Strain Relief – wire bundles shall be supported so that the solder connections are not subjected to mechanical loads. Conductors shall be provided with sufficient slack to preclude tension on the solder termination or conductor. (*NASA-STD-8739.3*)
- Through-hole component leads terminated straight through a PCB shall extend 0.5 mm (0.020 in) to 2.29 mm (0.0900 in.) beyond the pad surface. Leads may be bend up to 30° from the vertical plane to retain the part during soldering. (*NASA-STD-8739.3*)
- Component bodies shall not be in contact with soldered terminations. (*NASA-STD-8739.3*)
- The radius of a bend in the lead of a component shall not be less than the lead diameter or lead thickness. (*NASA-STD-8739.3*)



# Exemplar wiring

