Engineering Design

General Project Requirements

Senior Design Project

Electrical and Computer Engineering Department

August 2024

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Scope

This document describes the general requirements for student engineering projects conducted as part of a course, thesis, or independent study in Electrical and Computer Engineering (ECE) Department at Lafayette College. These requirements are applied in addition to and do not replace other requirements, rules, laws, and standards imposed by the various professors, academic departments, the engineering labs and shops, the college as a whole, government (local, state, and federal) as well as overarching societal and ethical norms.

Meeting all requirements is the highest priority for a design engineer. Unfortunately, requirements are sometimes in conflict with each other. Should two requirements seem in conflict based on a given design, as a general principle the design should be changed so that both requirements are met, if reasonable to do so. If it is not possible or reasonable to change the design to meet both of the conflicting requirements, the design engineer shall work with "the customer" who generated the requirement, or in conjunction with project management, Lafayette engineering professors, other authorities, and Lafayette administrative departments (Public Safety, Plant Operations, etc.), to resolve the conflict.

General Project Requirements

The following requirements apply to all Senior Design Projects in ECE Department.

GPR001: Documentation

Complete and accurate documentation must be provided with all projects. These documents shall include documents for mechanical and electrical fabrication, test results, software development kits, maintenance manual, user manual, specification compliance matrices, and technical papers. All documentation shall be accumulated in electronic form, centralized in a project web site, and thoroughly indexed.

Data items with privacy concerns (e.g. individual status letters) are delivered to course instructors and posted to a private area (e.g. Moodle). All other data items shall be delivered both to the course instructors and to the project web site. In the case of moderate sized PDF documents, the document should be emailed to course instructors and posted on the course web site. For larger deliverables, email notice may be sent to course instructors along with a URL of the deliverable as placed on the web site.

Text documents shall be formatted using a word processor in a professional style.

1. All drawings shall be complete in accordance with the standards established in engineering courses, such as ES 101, ME210 and ECE491, that are acceptable by the Engineering Machine Shop for fabrication. In addition, drawings must
    a. Be legible and neat – freehand sketches are unacceptable
    b. Exactly and unambiguously describe the most recent version of the part or assembly, including any bug fixes or improvements
    c. Give all critical dimensions
    d. Specify dimensional units unless a clear convention is established.
    e. Specify all materials
    f. Have a Lafayette or project specific border with completed title block that includes correct names, dates, part name, number, etc.
    g. Include the name of a specific individual requesting the part, with their full name, email, and phone number.
    h. Parts must have a unique part number. Assembly drawings and bill of materials (BOMs) should use these part numbers consistently.
    i. A part drawing should show the part number somewhere in the title block, the part number should be included in the drawing file name, and the part number should be marked on the part itself at some inconspicuous location using an indelible marker, metal stamp, or other permanent marking system.
    j. Any drawing submitted to the Lafayette Engineering Machine Shop for fabrication must be approved and signed by the designer, the team project engineer, and relevant faculty. “Rough” sketches without approval signatures may not be submitted to the shop.
2. Final drawings of fabricated parts must be indexed and archived on the project web site in PDF form. It should be possible to click on a drawing and open it directly without needing to download and unzip an archive or install CAD software.

3. Students may not submit un-reviewed "sketches" to the machine shop for fabrication. All drawings must be prepared according to GPR001 standards, archived on the web site in PDF format, and bear multiple review signatures along with the name, email, and cell phone number of the responsible individual BEFORE being submitted to the machine shop.
4. All original paper documents should be scanned and stored electronically. The original should be disposed of per GPR012.
5. Test reports for mechanical systems, hardware and software must show the date/time of testing, name and signature of the tester, and name/signature of any witnesses.
6. For all electronic PCB designs the following fabrication documents are required: dated, and numbered schematics or mechanical drawings on the standard drawing format, circuit net-lists, bills of materials, artwork, assembly drawings, and all other files and instructions necessary for CAM or manual manufacturing. The source files for fabricating PCBs and editing linked schematics shall be clearly identified and preserved.
7. For all mechanical assemblies the following fabrication documents are required: mechanical drawings on the standard drawing format, bills of materials, assembly drawings, and all other files and instructions necessary for CNC or manual manufacturing and assembly. The GCode source files or *.dxf files for fabricating parts on the CNC tools shall be clearly identified and preserved.
8. Documentation must be provided both for original designs and for any subcontracted designs. For purchased vendor components within the design, all vendor manuals and documentation shall be retained with the system. Proper mechanical drawings are required for fabricated mechanical parts. Manufacturers data sheets and interface drawings are required for all purchased components.
9. For software and firmware designs: Source code, and executable binaries for all applications; Verilog, constraints and configuration bitstreams for FPGAs; and ROM image files in commonly accepted JED or HEX formats for all PLDs.
10. Videos may be posted on YouTube or other cloud services, but a physical copy of the video in a file format that plays reliably on most PC/MAC/Linux computers must be included as part of the website archive.
11. All documentation must be provided and delivered in electronic form. Emailing a description of a document along with a URL into the project web site is an acceptable and desirable form of delivery. The use of standard and portable document formats (e.g. PDF, TXT), must be used so that the documentation can be viewed on any computer without the need for proprietary applications. Nevertheless, along with a viewable PDF version of every document, the original source format of the document (.docx, .vsd, etc.…) must be archived on the site. The documentation must be arranged in an organized and professional manner on the project web site. Although documents, photos, and videos may be posted temporarily on Google or YouTube or other cloud services for convenience, it's important that the team archive the original files on college-controlled networks (eg, the project web site) as well as on non-volatile media delivered to the course instructors.

12. To promote the College in general and the ECE Department in particular, documentation, hardware, and software shall be marked with the name of the college (using the official logo) along with the words "Electrical and Computer Engineering" in a similar sized font. All circuit boards, major assemblies, enclosures, racks, and any significant hardware subsystem, as well as all software modules, files, "About" screens, "splash screens" shall be so marked. In addition, the names of project team members may be added in a professional and tasteful way to titling on documentation, hardware, and software.

GPR002: Purchasing and Budget

1. **No expenditures will be approved till the project has developed a detailed budget.** All purchases must fit within pre-established budget constraints.
2. Any direct item to be purchased must be requested on a Lafayette Engineering Department Purchase Request form. An ECE professor must approve all requests.
3. Purchase requests must be archived on the web site.
4. The team shall keep a binder or spreadsheet with all approved purchase request forms. These should be tracked by the team against orders and received material. It is recommended that a single individual or small group be assigned for managing material procurement.
5. The college's purchasing agent will not accept unapproved requests, nor will they accept requests that are not on the standard form. Purchasing requests may be entered only on certain days. Basis for approval will be the degree to which the expense fits with the project plan of record. In general, overnight shipping will not be approved.
6. Running totals of costs incurred should be updated daily or even in real-time if necessary, especially when approaching critical limits or deadlines. Updated cost reports and budgets shall accompany requests for major purchases.
7. Received material without special safety considerations may be stored in the empty cabinets and shelves in senior design spaces as approved by faculty. It is the responsibility of the team to receive, inventory, and preserve the stock of received material.
8. In exceptional situations certain "big ticket" items must be purchased for the project with funds that are outside the general project budget.
9. Non-budget funding for such items may be sought from the Engineering Division subject to the approval of ECE faculty and department head. All such requests much be accompanied by written justification.

GPR003: Hazmats

Hazardous materials should be avoided in designs. If use of a hazardous material is essential to the function of the design and there is no non-hazardous alternative, the use of the hazardous material must comply with the Lafayette College Chemical Hygiene Plan.

All materials used in electronic circuit fabrication must meet 2002/95/EC RoHS directives. NiCd or Lead-Acid batteries may not be used in new designs.

Any liquids: water, coolant, brake fluid, resin etc. must be stored in properly labeled containers. Liquids that degrade over time must also be marked with the date received. All materials used on the wheelchair must have the accompanying MSDS information stored both on-line and physically in the workspace.

Any portion of the design or prototype that is discarded must be discarded according to the Lafayette College Chemical Hygiene plan. Also, projects should discard the collected electronic waste in an ecological-friendly manner as per the 2002/96/EC WEEE directive, either by ecological disposal or by reuse/refurbishment of the collected waste.

GPR004: Safety and Good Practice

All work shall comply with good industry practice that enhances reliability and maintainability. Students ARE EXPECTED to know ALL the rules and practices listed below.

General

1. Project activities must adhere to the general Lafayette College safety policy, possibly augmented by any Engineering Department or Laboratory safety rules.
2. A project team member must be designated project safety officer. It shall be the project safety officer's responsibility to ensure that all activities adhere to the project safety plan.
3. Students may not work, or be in the laboratory, machine shop/project rooms while others work, when impaired. Impairment includes being under the influence of alcohol or drugs (including prescription or over-the-counter medication), exhaustion, sleep deprivation or any other condition that adversely affects one's judgment.
4. Any project that develops AC RMS or DC potential differences greater than 30 Volts between any two points within the design (other than at the unmodified mains input side of a UL listed commercial power supply) must adopt and implement an electrical safety plan before any circuits are powered. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants. Faculty must approve the safety plan. The plan must be posted in the work area.
5. Safety glasses must be worn by everyone in mechanical work areas.
6. All work areas must be kept clean.
7. In the event of an emergency call public safety immediately by dialing 4444 (610-330- 4444 from a cell phone) and be prepared to give the following information:
    - Building name
    - Room number
    - Type of emergency (e.g. fire, injury, chemical release)

    Emergencies include but are not limited to:
    - Deep lacerations
    - Loss of consciousness (for any reason)

- Sickness from fumes (from known or unknown sources)
- Electrical shock (even if the person remains conscious)
- Accidental ingestion (even without symptoms)
- Eye injures such as impact to the eye (even without symptoms)
- Chemical burns

8. As soon as possible after an incident has occurred, students involved must report the incident to their faculty advisor. The faculty advisor will report the incident to the head of the department.
9. Color coded wiring in accordance with applicable industry standard color codes (e.g. NFPA 79 or UL508 for power wiring, EIA/TIA 568 for network wiring, etc.).
10. Wire and cable must be marked with gauge and temperature rating.
11. Clear labeling of all controls and indicators.
12. An obvious and clearly labeled system-wide power shutdown switch.
13. Silkscreen on PCBs that includes reference designators, noted power supply voltages and other critical signals. Silkscreen must show a Lafayette College logo, leopard paw icon, the words "Made in USA", the words "Electrical and Computer Engineering", assembly number and revision, and designated locations for serial numbers to be attached or written. PCB bottom copper should have text indicating the board part number and rev.
14. Fuses shall be mounted in UL listed sockets or holders and at least 5 spares must be included with system delivery; breakers shall be resettable. All are readily accessible per maintainability requirements.
15. Service loops must be included on all cable harnesses.
16. Access panels must be provided on enclosures that contain components that require routine access.
17. Software/firmware developed must adhere to the principles and practice established in Lafayette College course CS205 and ECE 414. Source code must be maintained under configuration control.
18. FPGA Logic shall be defined in HDL according to the rules and guidelines established in Lafayette College course ECE 211 and ECE 212.
19. Embedded computer processors shall have reset buttons. These buttons must be readily acceptable for maintenance, but not so easy to hit that they degrade reliability.
20. Major, visible enclosures shall have pilot lights, indicators, meters, displays, and other features that allow observers to be able to tell what is "going on" within the box without need for extra equipment.
21. Power LEDs shall be green. Red LEDs shall be reserved for error or exception conditions. Yellow and blue LEDs are used for status indications. Microprocessors shall have a "heartbeat" LED that blinks when working code is running.
22. All measurement indicators shall be labeled with units.
23. Wiring connections shall be insulated with heat shrink tubing or other rugged material. Electrical tape may not be used for insulating wire connections.
24. Circuits must be enclosed either by fully grounded metal enclosures, or fully insulated non-metal enclosures. PCBs may not be mounted directly to the outer walls of enclosures with nut/bolts pairs and loose standoffs. The use of an internal "chassis plate" for mounting electrical parts is encouraged.

25. Nut/Bolt fastener pairs may not be used within electrical assemblies. Use captive fasteners: PEM press fit fasters, threaded holes, clip nuts, or similar.
26. All fasteners should include suitable flat washers and lock washers.
27. Every enclosure must be labeled both externally and internally. All cables and wiring harnesses must be labeled. Labeling must be consistent with the ICD.
28. Every cable between assemblies shall have at least one dedicated current return within that cable. These returns shall carry all the return current for signals in that cable. Chassis ground may not carry return current except in a fault condition.
29. Cables and wires shall connect to assemblies and boards by means of suitable connectors. The use of stripped wire into "screw terminals" is strongly discouraged, especially for wire/board interfaces.
30. Connectors must use strain reliefs to prevent mechanical stress on the pin-wire connection.
31. Connectors must be in accessible locations with sufficient "hand grip" room.
32. Crimped pins must be assembled using a proper crimping tool. The wire size and type must be compatible with the pin.
33. Current drain analysis must be provided for all power supplies. Each supply voltage must have a current rating with a 50% safety factor over the anticipated peak current.
34. All resistors or other parts dissipating more than 25 milliwatts shall be identified and analysis shall be provided that shows all such parts are properly rated for peak and average power dissipation and have a proper heat sink and fan, if necessary, that provides adequate cooling over the ambient temperature range.
35. Fans should be protected with grilles and filters. EMI analysis must consider the fan opening and specify EMI tight grillwork if necessary.
36. Components must be cooled such that the temperatures of accessible surfaces are no greater than 60° C. If normally closed assemblies contain parts that may be hotter than 60° C and those assemblies have a cover or access panel or other enclosing structure that may be opened during routine maintenance, a "Caution HOT" label shall be affixed on the cover.
37. Power dissipation rating of parts shall be 50% overrated over the required temperature range.
38. Working voltage of capacitors shall be 25% overrated above the peak voltage anticipated, including all expected glitches, spikes, and tolerance limits.
39. Project activities must adhere to the general Lafayette College safety policy, possibly augmented by any Engineering Department or Laboratory safety rules.
40. Any project that develops AC RMS or DC potential differences greater than 30 Volts between any two points within the design (other than at the unmodified mains input side of a UL listed commercial power supply) must adopt and implement an electrical safety plan before any circuits are powered. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants. Faculty must approve the safety plan.
41. All equipment developed must comply with applicable national standards. Installations of electric conductors and equipment that connect to a building main supply of electricity must be designed, constructed, operated and maintained in accordance to The National Electric Code (NEC) ANSI/NFPA 70.

42. Any interconnection with the Lafayette College power grid is subject to the approval of Plant Operations. Any interconnection with the Lafayette College campus computer network is subject to the approval of the Information Technology Services department.
43. Use and design of lasers shall be in accordance with American National Standards Institute (ANSI) Z136.1-2000, "American National Standard for Safe Use of Lasers". Only low power Class I, II and Class IIIa (<5 mW) lasers should be used. If project requirements necessitate higher power, the project must develop and implement a laser safety plan before any laser work begins. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants.
44. All projects that involve RF power of any level must be designed to ensure that participants are not exposed to RF in excess of the recommended exposure limits adopted by the FCC (most recently in 1996, but note the proposed rule change in 2003). If project requirements necessitate radiated RF power in excess of 100 mW, the project must develop and implement an RF exposure safety plan before any high-power RF work begins. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants.
45. Projects that contain recognized hazards must develop a project safety plan. Such hazards include but are not limited to high altitude, operation at sea, on lakes, or in rivers or mines, exposure to electrical, chemical, biological, radiological, or psychological hazards.
46. All projects that involve machinery that create hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks, etc., must develop and implement a machinery safety plan before any machinery work begins. At a minimum, the plan must address US Title 29 CFR Part 1910 Occupational Safety and Health Standards, Sub Part O, Machinery and Machine Guarding.
47. Work is primarily performed in the student machine shop under the direct supervision of a technician or faculty advisor weekdays between 8 AM–3:45 PM. 3:45–4 PM is reserved for cleanup. In special cases the students can work in the shop at other times under the direct supervision of a technician or faculty advisor.
48. Students cannot use the tools in the mechanical areas until they have reviewed the procedures with a supervising technician (faculty advisor or shop personnel). A list of the tools and applicable procedures are available at me.lafayette.edu/safety
49. Students will consult with technicians about the manufacturability of designed parts. Dimensioned drawings must be submitted to the supervising technician. In most cases the machine shop staff will complete fabrication after the consultation process.
50. Testing of any prototypes requires a written testing plan and risk assessment be completed and documented by the students and approved by the faculty advisor in advance of the test.
51. Prototype testing is restricted to the hours of 9 AM to 6 PM.
52. Parts should be fully finished with no sharp edges of corners.

GPR005: Reliability

The system wide Mean Time Between Failures (MTBF) must be greater than 1000 hours over the system lifetime. Reliability must be demonstrated in the test plan both by analysis and by inspection. Failures are defined as anything that causes system requirements to be missed. Failures include, but are not limited to, computer software lock-ups, shutdowns caused by overheating, automatic operations stalled by exceptions or requests for human intervention, as well as random component failure.

1. For reliability analysis, the use of MIL-HDBK-217, Bellcore TR-332, or other equivalent techniques are encouraged for the analysis. Every part and subsystem in the full BOM must be explicitly considered in the MTBF analysis.
2. Parts with power dissipation over 25 milliwatts shall be identified and the reliability analysis shall include reliability derating of these components based on the expected dissipation.
3. In addition to the analysis, a reliability inspection shall be conducted during ATP where the system is shown to operate for 24 hours without any obvious failure.

GPR006: Software and Firmware Maintainability

A software maintainability plan must be developed and reviewed for every complex software subsystem. The plan should describe the overall approach to software maintainability and provide thorough answers to the following questions. Evidence must be provided to support assertions.

a. How will the software be installed on new hardware? What happens if the hardware goes obsolete?
b. How are errors and exceptions handled? How are logs viewed? How are exceptions configured and modified as requirements change?
c. How is backup performed? What is the restore procedure?
d. How is a fresh system deployed and validated on new hardware?
e. Are system logs and data files automatically trimmed? Do they grow and require manual trimming or offloading? If so, how is this accomplished?
f. What is the design of the system API and how will this design support ongoing reliable operation, maintenance and expansion?
g. How is system configuration maintained? Will the system auto detect hardware configuration changes or will configuration maintenance be required? If the latter, what is the consequence of misconfiguration? How will the software function when only some of the system hardware is available? Are demo or simulation stubs available for major hardware?
h. How is system configuration checked? Are tools provided for generating valid configurations?
i. What tool chain will be used? Is the tool suite up-to-date and actively supported? Is the tool suite mature enough to have stable functionality? How is the tool chain installed in a new development system.

j. What third party software will be incorporated into the system? How will this be maintained, upgraded, or patched during the life of the system?
k. How are requirements in GPR007 met?

In addition, software and firmware must meet the following maintainability requirements.

1. All software source code must be maintained under configuration control, either in on-campus or "cloud" repositories. Nevertheless, complete release snapshots must be archived on the project website.
2. The system must start from cold power-up and boot to full operational status without requiring user interaction beyond enabling power and safety procedures.
3. Any PC software must be packaged for installation with a SETUP.EXE, RPM, JAR, "make install" or equivalent installer allowing it to be installed easily on any compatible computer.
4. Configuration parameters, calibration factors, preferences, and options shall not be hard coded within the software source code. It shall be possible to alter these various factors without recompiling software or physically disassembling hardware. Altered configuration parameters must be persistent through power cycling and reboots. The system must have a function to initialize itself with the same (factory default) configuration content if requested.
5. All data and configuration files must be in a generally supported format (e.g. JSON, XML) or the format required by a mature and well supported application (e.g. MySQL database files, Berkeley db, etc.). The use of custom formatted ASCII or binary files for configuration or data storage is not permitted. Files shall be accessible either through removable media or network file transfer or both.
6. Cross references in configuration files shall use human readable text identifiers, not cryptic numeric codes.
7. Log files, data files, and any other files that grow over time shall be automatically trimmed by system software.
8. A scheme for automatic system backup of data storage shall be provided.
9. To the largest extent possible, the use of passwords shall be avoided. If the use of a password is unavoidable for serious security reasons, the password must be archived in a clearly documented location, and the user manual shall explicitly provide a scheme for password recovery.
10. The use of removable media (thumb drives, flash media cards) is permitted for configuration parameters, offline storage, access, and backup. If removable storage is used for configuration, the system must have the inherent capability to operate without media, and to initialize blank media with sane configuration content.
11. Enumerated devices, such as USB, must be automatically discovered by the system and assigned correct port designations such that the system operates correctly after re-enumeration without any interaction or re-programming by the user. Port designations may not be "hard coded" in the software or firmware.
12. Any cell phone software must be packaged and available from an online "App store" for easy installation on any compatible phone without requiring special alterations of the phone such as SDK installation or jailbreaking.

GPR007: Final Disposal of Projects

Projects may be stored for future work, placed on display, or discarded. Time must be included in project schedules for final disposal.

1. If a project is to be stored, all its materials must be collected together in a single location. If possible, these materials should be enclosed in a sealed container, locked cabinet, or secure room that contains only these materials from one project and no other. If certain parts are impractical to store with the bulk of the project materials, these separate parts must be clearly labeled so their association with the stored project is obvious.
2. Projects placed on display may have portions not on display. The un-displayed portions shall be either stored or discarded as described herein.
3. Portions of projects or complete projects that are discarded must be discarded in accordance with Hazmat procedures described herein.
4. Test equipment moved from labs shall be replaced in its original location.
5. Trash, loose wires, scattered components, and other detritus resulting from frenzied development and testing shall be cleaned up.
6. Paper documents that have been scanned per GPR001 shall be recycled.
7. The project web site must be updated constantly with the most recent versions of all documents. The documents on the final web site must match the delivered system. Obsolete documents on the web site shall be removed.
8. The entire design, or some major functional subsystem of the design, must be suitable for continuous, unattended display as a self-contained, active demonstration that would excite the interest of students, faculty, and other ECE Department visitors. Such demonstrations must meet the following requirements:

    - Demonstrations must fit in a compact public area and operate safely and without unreasonable disturbance of its neighbors.
    - In demo mode, computer screens must periodically display the Lafayette ECE logo, list of team members, and a team photo to the extent permitted by the graphics capabilities of the screen, and functional realizability.
    - If powered by building mains, the demonstration shall automatically restart after a power outage. User interaction with the demo is encouraged, but if activated by some passer-by, the demonstration must deactivate automatically after a short delay. The MTTR and MTBF of the demonstration must meet or exceed the project-level Maintainability and Reliability requirements given herein.