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UNIVERSITY OF COLORADO DENVER
Electrical Engineering Department
GRADUATE STUDY in ELECTRICAL ENGINEERING

INTRODUCTORY SUMMARY

The University of Colorado Denver, College of Engineering. Design and Computing (CEDC), offers undergraduate and graduate degrees in the disciplines of electrical engineering, computer science, cyber security, civil engineering, construction management, mechanical engineering, and bioengineering.

The electrical engineering M.S.E.E. degree, M. Engr degree and the CEDC' multidisciplinary Ph.D. in Engineering and Applied Science, offer exciting opportunities to pursue graduate degrees in a number of traditional as well as new areas of emphasis. The electrical engineering web site can be accessed at: http://www.ucdenver.edu/academics/colleges/Engineering/Programs/Electrical-Engineering/Pages/ElectricalEngineering.aspx

Practicing engineers can extend and update their professional capabilities through credit and/or non-credit courses, as well as earn graduate education in management, public policy, environmental science, computer science, or other areas of engineering through complimentary multi-disciplinary Master of Engineering programs offered by the College.

The Electrical Engineering Department offers graduate programs in electrical engineering with the following **areas** of concentration:

Communications, Controls, and Signal Processing
Microelectronics and VLSI
Electromagnetics and RF Engineering
Computer Engineering and Embedded System Design
Energy and Power Systems
Neuroscience
Quantum Computing

The Department offers graduate programs leading to the following degrees:

* Master of Science in Electrical Engineering (M.S.E.E.)
* Master of Engineering (M.Engr.)
* Doctor of Philosophy (Ph.D.) in Engineering and Applied Science

All graduate degrees are awarded and administered by the College of Engineering. Design and Computing, and the Vice-Chancellor of the Graduate School of University of Colorado Denver in cooperation with the Electrical Engineering Department.

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I. MASTER'S PROGRAM IN ELECTRICAL ENGINEERING

I. 1 Admission Requirements

Interested students with questions may contact members of the Electrical Engineering Department Graduate Committee by calling the department office at (303) 315-7520, visiting the web site or email electrical@ucdenver.edu. Application forms for all graduate degrees may be accessed on-line at the web site: https://soa.prod.cu.edu/degreeprog/applyDEGREEPROG_CUDEN/login.action. All applicants for admission need to submit complete credentials as are outlined in the instructions included in the on-line application.

To be considered for "regular" admission to the Master's program, candidates must meet the following minimum requirements: a BS degree from a reputable institution, either in Electrical Engineering, or in equivalent Math, Physics and other engineering disciplines and with Grade Point Average (GPA) at least 3.0, on a 4.0 scale. If the applicants GPA is below the minimum, the applicant can also submit additional evidence of adequate preparation for graduate study in the form of a GRE score can or an earned master's degree. A GRE scores is not required but can add value to an application. Satisfaction of minimum requirements does not guarantee admission. The substance of the student's curriculum and the grades obtained in the student's area of concentration are important factors in the consideration, and so are possible multiple repetitions of fundamental courses.

For those undergraduate students with degrees in science and non-electrical engineering wishing to pursue graduate study in the Electrical Engineering Department there is no restriction or constraint in being admitted into the M.S.E.E. graduate program. However, such applicants are responsible for having the knowledge of pre-requisite course requirements.

Students should plan a program of study in consultation with their departmental advisor(s), during the first semester of study.

I.2 Master of Science (MSEE) Program

Upon acceptance to the MSEE program, each student will be assigned a faculty advisor to help them with selecting their courses for the first semester. The student's graduate advisor will approve the student's curriculum, as complying with the rules and conditions in this document, and will supervise the student's thesis or when applicable (see below for thesis versus course only option). The list of graduate advisors in the EE Department is included in Section IV of this document.

To fulfill the requirements for the MSEE degree, the EE Department at CU Denver requires that, within a seven-year period, a candidate complete an approved program in one of two options: (a) a thesis option consisting of at least 30 semester hours or (b) a course only option consisting of at least 30 semester hours. It is also required that the MSEE candidate maintain a grade point average of 3.0 or higher. In compliance with the Graduate School Rules, the minimum grade **required** for a unit to count towards the required semester hours is "B minus" (2.7)**.** For the students in the thesis option, it is recommended that they attend the CEDC seminar series. For the students in the courses only option, it is **required** that they take the ENGR5150 seminar course for 1 semester and 0 credits. The ENGR5150 seminar course is a pass/fail; for passing a 75% minimum attendance plus a report on one of the seminars are required.

The EE department offers five areas of concentration at the Master level: Information Systems; Microelectronics and VLSI; Fields, Waves and Optics; Computer Engineering and Embedded Design; and Energy and Power Systems. The courses offered in each concentration area are listed in Appendix 1 of this document.

For both thesis and course only MSEE options, it is required that a student select a primary area of concentration and a secondary area of concentration among the six areas listed above, *in agreement with the student's graduate advisor* (the list of graduate advisors is included in Section IV of this document). The student must take at least four (4) 3-credit courses in the primary area of concentration and at least two (2) 3-credit courses in the secondary area of concentration, all these six (6) courses being selected from those listed in Section III and being offered by the CU Denver EE Department. Additional courses may be selected from any area of concentration among those in Section III that are offered by the CU Denver EE Department, where one (1) 3-credit course may be an independent study with one of the graduate faculty at the CU Denver EE Department and, where 1 to 3 credits maybe from an Internship. Students can get credit for 3 separate 1 hour Internships. It is emphasized that *a student may take no more than one independent study course. At least 21 course units must be taken from the CU Denver EE Department. At the discretion of the EE graduate committee, a maximum of nine (9) credits may be transferred from other programs.* The additional requirements dictated by each one of the two, thesis versus courses only, options are stated below.

- The thesis option allocates six credits to the Master's thesis, completed under the mentorship of the student's graduate advisor. In addition to the six (6) courses in primary and secondary concentration areas mentioned above, this option also requires two additional 3- unit graduate courses. *The latter courses may be selected via signed pre-agreement with the student's graduate advisor.*

Typical Degree Construct – Thesis Option

Primary Area (required)	minimum four courses, Appendix 1, CU Denver EE Dept.	12 CR
Secondary Area (required)	minimum two courses, Appendix 1, CU Denver EE Dept.	6 CR
One additional course (required)	CU Denver EE Dept.	3 CR
Thesis (required)		6 CR
Other course (required)	pre-approved by advisor	3 CR
Total (minimum)		30 CR

- *It is required by the Graduate School Rules that the student defend his/her Thesis in front of a three-member committee of graduate faculty.*

Typical Degree Construct – Course Only Option

Primary Area (required)	minimum four courses, Appendix 1, CU Denver EE Dept.	12 CR
Secondary Area (required)	minimum two courses, Appendix 1, CU Denver EE Dept.	6 CR
Other courses (required)	can include one additional seminar or graduate labs	12 CR
CEDC Seminar (required)	must be officially enrolled and submit a report	0 CR
Total (minimum)		30 CR

- The course only option requires a total of 30 credits, including a mandatory 1 semester - 0 credit of the CEDC seminar. Additional graduate courses are *selected with the signed pre-agreement of the student's graduate advisor.*

  - Each new course only EE MS students is be required to take at ***least three classes with a research project.***
  - The advisors is responsible for making the notation of the classes that meet this requirement.

- *The M.S.E.E. major advisor must be a full-time, UCD Electrical Engineering Department, graduate faculty member. Those currently satisfying these requirements are listed in Section IV of this document.*

Candidates with a B.S.E.E. degree from UCD Electrical Engineering Department can count 6 electrical engineering UCD graduate credits toward both undergraduate and graduate degrees, if their undergraduate GPA was at least 3.0. Double-counting applies only to credits earned at 5000-level or higher, and with a "B minus" (2.7) or higher grade.
BS Students in the EE Scholars program can count 12 electrical engineering graduate credits towards both undergraduate and graduate degrees, if their undergraduate GPA was at least 3.0.

I.3 Master of Engineering (M.Engr.)Program

A qualified student may enroll in the graduate program of the Department of Electrical Engineering to pursue the degree of Master of Engineering. This program is broad-based and is designed especially for that person who wants to further their education in more than just one discipline. An example might be in engineering administration where course work in business management would supplement engineering studies.

A minimum of 30 credit semester hours of academic work *acceptable to the Advisory Committee (within the rules established by the College of Engineering. Design and Computing)* will be required for the degree Master of Engineering. In compliance with the Graduate School Rules, the minimum grade required for a unit to count towards the 30 semester hours is "B minus" (2.7). To couple this degree with electrical engineering, at least 15 of these hours must be 5000 level or above in electrical engineering courses, and must be taken in the CU Denver Electrical Engineering Department. As many as 12 hours can be taken outside of electrical engineering. A 3-credit hour master of engineering project is **optional**. The project should cover some area of creative investigation performed by the student and may relate directly to his/her professional work and must written up as a report and also defended orally before the Advisory Committee.

Typical Degree Construct – M Engr.

Electrical Engineering (required)	minimum 5 courses, Appendix 1, CU Denver EE Dept.	15 CR
Outside EE courses	can be in EE or other graduate courses at CU Denver	12 CR
Project (optional)	optional, counts toward the 30-credit total	3 CR
Total (minimum)		30 CR

***If you choose non- project you will need 15 credits of outside EE courses*.

II. DOCTOR OF PHILOSOPHY (Ph.D.) PROGRAM

The College of Engineering. Design and Computing (CEDC) at the University of Colorado Denver (CU Denver) admits students into the program in Engineering and Applied Science (EAS PhD). Under the CEDC PhD program, a successful doctoral student receives the degree "Doctor of Philosophy in Engineering and Applied Science". The program is multidisciplinary with four departments of the College serving as host departments (Civil (CE), Computer Science and Engineering (CSE), Electrical (EE) and Mechanical (ME)) and all five departments (Bioengineering (BIOE), CE, CSE, EE and ME) offering secondary disciplines of concentration. The secondary concentration may also be chosen from another College/School at CU Denver. Applicants to this program apply to and enter the program through one of four departments of the College: CE, CSE, EE, or ME, called the host department. All applicants for admission need to submit complete credentials as are outlined in the instructions included in the on-line application.

The web site for the on-line application is: http://www.ucdenver.edu/admissions/doctoral/pages/index.aspx. For students whose primary concentration is Electrical Engineering, ***Engineering and Applied Science-PhD*** should be selected under Field of Study. Then, ***Electrical Engineering*** should be selected as the applicant's host department in the Background Information field,

II.1 Admission Requirements

Following are the admission requirements for the CEDC PhD degree. This document should be used by the department Graduate Committees in making admission decisions.

Materials to be Submitted by the Applicant

- Application for admission
- GRE scores (optional but recommended)
- Two letters of recommendation (can be waived for CU Denver graduates)
- Two copies of all transcripts

- Processing fee
- Personal statement of academic and research interests, including intended primary concentration within the host department
- International applicants whose native language is not English are required to submit TOEFL scores

Application Process
A student will apply to and enter the program through one of the four host departments of the College: Civil Engineering (CE), Computer Science and Engineering (CSE), Electrical Engineering (EE) or Mechanical Engineering (ME).
The Admissions Committee of the Electrical Engineering Department consists of the entire graduate faculty. When an application is received, the PhD Coordinator alone or with the aid of other faculty members performs a preliminary review of the application documenting strengths and weaknesses of the applicant. The application is then presented at the next faculty meeting. An admission decision is made by a majority vote of the present graduate faculty members with voting rules as stipulated in the Department bylaws. Acceptance and rejection letters are sent out by the Department Chair. Letters describing any financial support that is offered to an accepted candidate are sent by the faculty member that is the PI of the financial source and the letter becomes part of the student file.

Application Deadlines
The application deadlines for fall admission are April 15 for international applicants and May 1 for domestic applicants. The application deadlines for spring admission are September 15 for international applicants and October 1 for domestic applicants.
Consideration for the merit-based fellowships from the Department of Electrical Engineering requires submitting a complete application for admission by the first fall semester admission deadline of March 1. No extra materials are required beyond those of the application for admission.

Prior Degree and GPA Requirements
A student does not need to possess a Master's degree before applying to the CEDC PhD program. The minimum requirements for admission to the CEDC PhD program are a B.S. in one of the corresponding engineering disciplines, or an equivalent degree in Mathematics, Physics, Chemistry or Biology, from a reputable institution, with Grade Point Average (GPA) at least 3.0, based upon a 4.0 scale. Satisfaction of minimum requirements will not guarantee admission. The grades obtained in the student's area of concentration will be an important factor in the consideration.

Prerequisites for Courses
Students with undergraduate degrees in mathematics, science, or other engineering or non-engineering fields are eligible to apply for admission into the CEDC PhD program through one of the engineering host departments. However, all students must fulfill any prerequisite course requirements for graduate courses, either by taking courses or showing required knowledge.

GRE Scores
GRE scores are not required but can increase the chances of acceptance. Preferred minimum GRE scores are 150 Verbal, 153 Quantitative, and 3.5 for Analytical Writing for tests taken August 1, 2011 or later. For tests taken prior to August 1, 2011, preferred minimum GRE scores are 450 Verbal, 680 Quantitative, and 3.5 for Analytical Writing.

TOEFL Requirements: An international student whose undergraduate language of instruction was not English, should have a minimum TOEFL **75 IBT / 537 PBT**

TOEFL Subscores	
Reading	15
Listening	15
Speaking	18
Writing	17

IELTS Minimum Score Accepted: **6.5**

The TOEFL/IELTS requirement can be waived if an applicant has graduated from the ESL Academy. Information regarding other considerations for exemption, including country of citizenship/origin, and special circumstances can be found at http://catalog.ucdenver.edu/content.php?catoid=25&navoid=7154.

IELTS Subscores

Reading	5.5
Listening	5.5
Speaking	5.5
Writing	5.5

PTE ACADEMIC Minimum Score Accepted: **51**

The Pearson Test of English (PTE Academic) is currently in a pilot review at the University of Colorado Denver. We will accept a 51 PTE Academic score with the following subscores:

Reading	44
Listening	44
Speaking	49
Writing	47

Exempt Countries: Australia, Belize, Botswana, Canada (except Quebec), Commonwealth Caribbean, Ghana, Great Britain, Ireland, Kenya, New Zealand, Scotland, Singapore, South Africa, and Zimbabwe.

An applicant who does not meet these requirements can petition the University of Colorado Denver Graduate School for admittance, as either a Regular or Conditional degree student.

Financial Support
Admission to the EAS PhD program is based on academic credentials alone and is separate from financial support. Admission to the program does not guarantee financial support. Doctoral candidates can be supported by research grants to faculty members, fellowships and scholarships, or teaching assistant and instructor positions. Admitted candidates should discuss financial support with their assigned advisor.

Transfer Credit
Request for transfer of credit will be considered on a case-by-case basis. This includes students possessing a Master's degree. In keeping with the Rules of the Graduate School, doctoral students may transfer in a maximum of 21 credit hours, including graduate courses completed at the University of Colorado. Students possessing a Master's degree, including those that obtained the degree from the University of Colorado, will be required to take a minimum of 9 additional course credit hours. Additional imposed course credit requirements will be considered on a case-by-case basis. All requests for transfer of credit must be made upon enrollment and will be granted solely at the discretion of of the pertinent CEDC host department. The Electrical Engineering department adheres to the following guidelines on transfer credit for PhD candidates in addition to rules at the College level.

- University of Colorado Denver ELEC Graduate Courses - Allow transfer for all 5000 level lecture courses with grades B and above up to 21 credits.
- Non University of Colorado Denver Graduate Courses – Allow transfer of up to 15 credits of courses with grades A- and above. We defer to the international office in assessment of grades from non-USA institutions.
- Independent study courses taken as part of the BS or MS degree will not be taken into account for transfer credit.
- Courses not taken within the last 5 years will in general not be transferred as per CEDC rules. Transfer of any courses taken more than 5 years ago requires special validation to ensure that both the course content is still current and the student still retains sufficient knowledge of the content.

- Credit will only be transferred after the student has completed 1 semester of enrollment at CU Denver and earned minimum 3.00 GPA as per Graduate School Rules

II.2 Rules and Regulations

Following are the Rules and Regulations for the EAS PhD degree.

Host Department
Applicants to the EAS PhD program apply to and enter the program through one of four departments, called the host department, of the College: CE, CSE, EE, or ME. The student chooses the host department whose course offerings match with his/her desired primary area of concentration. As this Ph.D. program is multidisciplinary, a student must take courses from both a primary and secondary concentration.

Selection of Primary and Secondary Discipline
For his/her research and study area and with the assistance and approval of his/her advisor, a Ph.D. candidate will select a primary area of concentration within his/her host department, or discipline. With the agreement of his/her faculty advisor, the student will also select a secondary discipline outside of the student's host department, which could be any one of the remaining CEDC departments, including the BIOE department. The secondary discipline may also be chosen from another College/School at CU Denver (e.g., the Mathematics or Physics department in CLAS). The student's advisor(s) will be instrumental in the selection of a secondary discipline that supports and complements the primary area of concentration in his/her primary discipline. At least one of the student's research committee members must be from the department that supports the student's secondary discipline concentration.

Graduate Advisor and Research Committee
Upon acceptance to the EAS PhD program, each student will be assigned a temporary graduate faculty advisor from the ranks of full-time, CEDC host-department graduate faculty who possesses a Ph.D. degree in Engineering, Mathematics or Sciences to help the student select courses for the first semester. During the first semester, this advisor will also help the student plan a long-term program of study, which should be submitted to the respective host department for approval. In the first year of graduate studies, each EAS PhD candidate must select and have an agreement from a permanent graduate faculty member from the ranks of the full-time, CEDC host-department graduate faculty who possesses a Ph.D. in Engineering, Mathematics or Sciences to be the student's research advisor or the student will be discontinued from the program. The advisor will assist the student with the design of his/her course curriculum, will supervise the student's dissertation, will help the student form a five-member research committee that will approve the student's plan of study and will help mentor the student's research. The research committee must include at least two faculty outside the student's home department, at least one of whom from the department that supports the student's secondary discipline concentration and at least one of whom outside of CEDC, while all members of the committee must possess a Ph.D. degree in Engineering, Mathematics or Sciences.

Coursework Requirements
The coursework requirement is 30 credit hours (i.e., 10 courses each of which is 3 credits) for all students. Students must take at least five courses in the primary area of concentration in the host department and at least three courses in the candidate's secondary discipline. The two additional courses may be selected from any discipline or areas of concentration within disciplines among those listed in the graduate documents of the CEDC departments or other colleges in the University. Other courses may be recommended by the student's advisor. As already stated above, to maintain the multidisciplinary feature of the program, the three courses in the secondary discipline of concentration must come from outside the student's host department; from any of the remaining four departments of the College. The secondary discipline may also be chosen from another College/School at CU Denver. For students with more than 15 units of transfer credits, the course distribution will be decided on a case-by-case basis. To register for any of these required courses, the student must first obtain the signed approval of his/her graduate advisor(s).

Independent Study Courses
A student may take one, but no more than one, independent study course from one of the CEDC graduate faculty.

Table 1 – Course Requirements for CEDC PhD in Electrical Engineering

	Primary Discipline (Electrical Engineering)	**Secondary Discipline (Non-Electrical Engineering)**

Required (24 credit hours)	15 graduate credit hours of coursework (ELEC 5XXX). (Must include required courses in chosen area of concentration (e.g., Electromagnetics)	9 graduate credit hours (5XXX) in a single secondary discipline (non-ELEC) approved by PhD committee
Options (6 credit hours)	• At least 6 additional credit hours must be taken at 5XXX level. Can be ELEC course, or secondary discipline. • Up to 3 hours of independent student allowed (ELEC or in secondary discipline)	

Research Requirements
For the research/dissertation requirement, an additional 30 dissertation units are required with supervision by the student's graduate advisor(s). A student who successfully completes the 30-unit course requirement, but decides to not pursue the 30-unit dissertation requirement, may graduate with a Master's degree in the discipline of his/her primary concentration provided he/she has met the degree requirements of the host department.

Seminar and GPA Requirements
The candidate must maintain a grade point average of 3.0 or higher. In compliance with the Graduate School Rules, the minimum grade required for a unit to count toward the 30 semester hours of coursework is "B minus" (2.7). The College of Engineering. Design and Computing (CEDC) will require that all EAS PhD candidates take at least two semesters of the ENGR7150 seminar course, at 0.5 credits per each semester. The class is a pass/fail; for passing a 75% minimum attendance plus a report on one of the seminars are required.

Timing of Coursework
Each EAS PhD candidate will be expected to successfully complete at least fifteen credit hours of coursework during the first year of study. Exceptions to this will be considered on a case-by-case basis, especially for working students.

Preliminary Examination
Each PhD candidate is required to take the Preliminary Examination prepared by the full-time faculty of the EE department. The Preliminary Examination consists of two parts: (a) A general mathematics part (only written exam) and (b) an area exam (both written and oral exam). Each candidate is required to successfully complete the Preliminary Examination requirement by the end of his/her second year in the program, while he/she is allowed a maximum of two attempts. A candidate who fails to fulfill the Preliminary Examination requirements will be expelled from the program.

Comprehensive Examination and Doctoral Dissertation Defense
After successful completion of the Preliminary Examination, students will be required to successfully complete two additional examinations: the Comprehensive Examination and the Doctoral Dissertation Defense Examination. The Comprehensive Examination will be prepared by the candidate's dissertation committee and will be taken by the end of the candidate's third year of doctoral studies. Consisting of written and oral parts, its purpose is to evaluate the candidate's proficiency in his/her primary and secondary areas of concentration. A guide to the Ph.D. Comprehensive Exam is included in Section III.3 of this document. The Doctoral Dissertation Defense is the final examination and is designed to evaluate the originality and quality of the candidate's research. Upon successful completion of the Doctoral Dissertation Defense Examination, the Doctoral Dissertation will be submitted to the Graduate School.

Degree Conferred
Upon satisfactory completion of all requirements, the candidate receives the degree "Doctor of Philosophy in Engineering and Applied Science."

II.3 Guide to PhD Preliminary Exam

In the Electrical Engineering Department, the preliminary examination consists of an applied mathematics exam and an electrical engineering area exam (c.f., Figure 1). The applied mathematics exam is a written exam. The area exams have written and oral components and are focused on a graduate area within the field of electrical engineering. Passing the written part of the area examination is a prerequisite for the oral portion. The preliminary examination is offered twice a year at the beginning of the semester. **Each Ph.D. candidate can attempt each exam no more than twice**. A PhD candidate is required to have passed all components of the preliminary exam within two years of enrollment as a PhD student (before beginning the 5th semester of enrollment).

- **Applied Mathematics Written Exam**
  The exam consists of 10 problems of which the candidate must answer 8. Each graduate faculty member submits a problem for the exam that should take a well prepared student 20 minutes to complete. Students have 4 hours to complete the entire exam. The problems submitted by faculty for the exam must be newly created problems. Each faculty member submits two problems for the exam of which ten are chosen for the exam. The question content for the exam should be at the advanced undergraduate level that students would be exposed to in completing a BS in electrical engineering. Specifically, the exam covers the following topics:

  - Calculus I-III material (real analysis, series, multivariate calculus, vector calculus)
  - Differential Equations
  - Linear Algebra
  - Theory of Linear Systems
  - Probability and Statistics
  - Fourier, Laplace, and Z Transforms
  - Numerical Analysis

  The following four textbooks encompass the exam scope and should be used by students for preparation. These textbooks are used in the CU Denver undergraduate curriculum. Exam Questions can also cover the underlying mathematical background of the material in these texts.

  - *Calculus Early Transcendentals* 1st Edition by Briggs and Cochran (MATH 2411, MATH 2421)
  - *Differential Equations & Linear Algebra*, Third Edition, C. H. Edwards & D. E. Penney (MATH 3195)
  - *Linear Systems & Signals* 2nd, Edition by B. P. Lathi (ELEC 3316)
  - *Probability & Stochastic Processes* (Chap. 1-9) , 2 Ed. By Yates, Roy D. & Goodman, David (ELEC 3817)

  Candidates are expected to receive a cumulative score of 70% or higher to pass the exam. The exam is offered on the Friday of the first week of classes.

- **Concentration Area Written Exam**
  The candidate will choose a specialty area within the field of electrical engineering in which to he/she will be examined. The exam will consist of problems contributed by faculty members who have expertise in one of the two the chosen area (at least two faculty members are involved in administrating each area exam). Students will have two hours to complete the written exam. The content for the exam is at the advanced undergraduate level that students would be exposed to in completing a BS in electrical engineering and can additionally include graduate level material that is covered in courses at the MS level. Candidates must receive a cumulative score of 70% or higher to pass each area exam. The exam is offered on the Friday of the third week of classes of the semester.

  Concentration Area Oral Exam
  If the candidate has passed the concentration area written area exam described above, then he/she will be eligible for the oral exam in the concentration area. The oral will be conducted by the faculty members that conducted the written concentration area exam (at least two faculty members are involved in administrating the exam). All members of the graduate faculty have the right to attend the oral exam and participate even if they did not participate in the written concentration exam. The exam is offered on the Friday of the fifth week of classes of the semester.

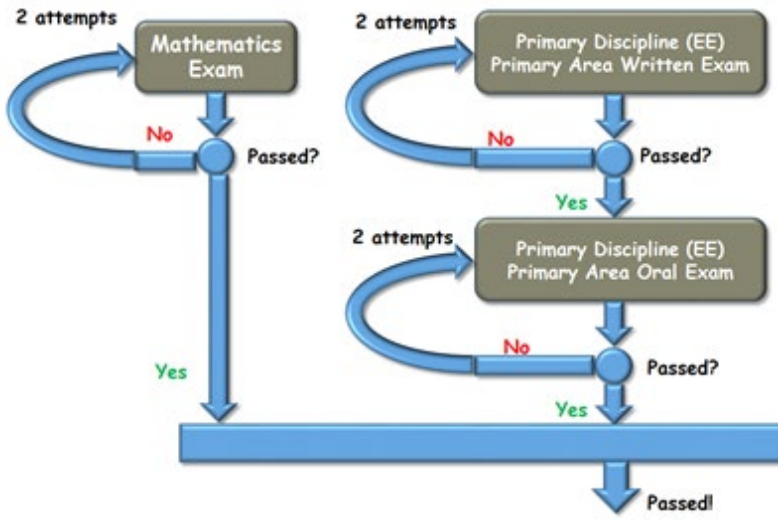

Figure 1. Illustration of the structure of the CEDC PhD Preliminary Exam in Electrical Engineering

II.4 Guide to PhD Comprehensive Exam

The PhD Comprehensive Exam is intended to test the candidate's ability to perform, present and discuss one's research. The following is an overall guide to be used by students when preparing for the exam.

The student will first prepare a written document, entitled *Thesis Proposal*, which describes his/her research objectives. The *Thesis Proposal* will subsequently be defended in the presence of the members of the student's Comprehensive Exam Committee. The proposal should give clear evidence of knowledge of the research topic and understanding of the research problem and related work. It should also include indication of the research methodology, expected results, and a (timeline) schedule up to the completion of the thesis writing and the doctoral defense. Upon successfully passing the comprehensive exam, the student is officially admitted into (PhD) candidacy.

- The Comprehensive Exam should be held within a year of passing the qualifying Preliminary Exam and by the third year of the student's enrollment in the PhD program.
- The Thesis Proposal must be submitted to the PhD Committee **at least three weeks prior to the exam**. This gives the committee sufficient time to carefully read the proposal and evaluate it. Failure to submit the proposal on time may result in having to reschedule the exam.
- The Comprehensive Exam Committee should be the same as the 5 member research committee described in the CEDC PhD Rules and Regulations. As such, the committee must include at least two faculty outside the student's home department (EE in the case of this document), one of whom must be outside of CEDC. The successful candidate will be expected to defend his/her dissertation before the same committee, which is referred to as the Ph.D. Committee in the remainder of this document.
- In compliance with the Graduate School rules, the application for candidacy form and the permission to take the exam form must be completed at least two weeks prior to the exam.

II.5 Guidelines on How to Write the Comprehensive Exam Report (*Thesis Proposal*)

- The *Thesis Proposal* should be between 15 and 25 pages (single-spaced format). Bibliographic references are not included in this page count (having more references is encouraged). While the page limits or formatting requirements are not strictly enforced, the Ph.D. Committee may question the reasons for a proposal length outside the norm. A template for writing the *Thesis Proposal* will be provided by the Department.
- A balance must be struck between satisfying space limitations and providing the most critical details. The proposal is not a binding agreement between the student and the Ph.D. Committee on the precise tasks that must be accomplished. Through frequent interactions with Ph.D. Committee members, the student may adapt specific elements of the research objectives.
- Three main criteria are usually applied in evaluating a proposal:

- Intellectual merit: What is the importance of the activity to advancing knowledge or understanding?
- Expected impact: How the proposed research may impact specific research communities or society as a whole.
- Feasibility: Are the stated objectives achievable within reasonable time constraints?

- Based on the above evaluation criteria, the Thesis Proposal should contain:

  - **Executive Summary:** An executive summary of the thesis proposal (1 or 2 paragraphs, and less than 1/2 page).
  - **Background**: An overview of the state of the art, which helps to show that the candidate has a good grasp of the relevant research fields.
  - **Objectives**: The overall objectives of the proposed research.
  - **Impact:** Clear arguments as to why the work is interesting and novel in terms of intellectual merit and expected impact.
  - **Technical Approach**: This section should outline the general technical component of the research, including an outline of the research and a clear description of theoretical or experimental methods that will be used to accomplish the research. In effect, this section should address what will be done, why it should be done, how it will be done, and how metrics will be used to measure success.
  - **Accomplishments to Date:** A brief summary of research results obtained so far by the candidate. This includes citing prior publications and current submissions produced by the student.
  - **Milestones:** A clear description of the remaining tasks and goals with a time table and an explanation of how the goals can be accomplished within the expected amount of time.

- The Thesis Proposal should *not* be

  - A preliminary draft of the thesis.
  - Particular chapters or parts of the thesis.
  - A survey of the candidate's research field.
  - An existing publication or technical report.

Oral Examination

The student is required to prepare a 40 minute research presentation to be presented to his/her Ph.D. committee. The presentation should include the topics in the student's *Thesis Proposal* and should cover a description of the problem, related background work, the proposed research objectives and approach, and research work completed by the student up to the time of the exam. The future work being proposed as part of the Comprehensive Exam is essential and must be included albeit the discussion of future work should be concise and brief. The student should be prepared to answer any questions from their committee, both during and following the presentation, on topics directly related and indirectly related to their proposed research. While different research advisors may have a slightly different perspective on what is important, the student will need to demonstrate that they are knowledgeable in the area of their research proposal and are able to apply their knowledge to new problems. The Ph.D. committee will also evaluate whether the research topic is appropriate and satisfies the requirements for a Ph.D. dissertation. The student's presentation portion of the oral examination can be attended by the public, but the Ph.D. committee reserves the right to a private question and answer session that is open only to the committee, the candidate and other faculty with graduate appointments.

I understand the Rules and Regulations, and my faculty advisor and I have devised a curriculum plan complying with them.

_____ Date _____

Student

_____ Date _____

Faculty Advisor

APPENDIX 1

ELECTRICAL ENGINEERING GRADUATE COURSES AT CU DENVER

(a) Information Systems (Communications, Controls, Signal Processing, Machine Learning)

Courses offered in the Fall semester
ELEC 5152 Introduction to Intelligent Transportation Systems
ELEC 5644 Intro to Medical Imaging
ELEC 5627 Graph Signal Processing

Courses offered every other Spring semester
ELEC 5637, Digital Signal Processing.
ELEC 5248, Digital Communication Systems
ELEC 5755 Grid Integration of Renewable Energy

Courses offered in the Summer semester
ELEC 5212 Fundamentals of Reliability Engineering

Courses offered occasionally upon demand
ELEC5252 Computer Communication Networks
ELEC 6000 Statistical Signal Processing
ELEC 5802 Control of Energy Systems
ELEC 5657 Detection and Estimation Theory
ELEC 5250 Information Theory
ELEC 5648 Blind Signal Processing,
ELEC 5276 Digital Control Systems
ELEC 5617 Random Processes for Engineers
ELEC 5466 Adaptive Control System Design
ELEC 5375 Engineering Neuroscience
ELEC 5446 Introduction to Modern Control Theory

(b) Microelectronics and VLSI:
Courses required for all majoring in the area
ELEC 5025 Device Electronics

Courses offered
ELEC 5005 IC Design
ELEC 5804 Printed Circuit Board Design
ELEC 5455-Computer Method for Device Electronics
ELEC 5555 VLSI Circuit Simulation
ELEC 5455 CMOS Design

(c) Electromagnetics & RF Engineering

Courses required for all majoring in the area
ELEC 5033 Advanced Electromagnetic Fields

Courses offered every Fall semester
ELEC 5133 Electromagnetic Radiation and Antenna

Courses offered every other Fall
ELEC 5333 Introduction to Computational Electromagnetics
ELEC 5334 Advanced Computational Electromagnetics

Courses offered every Spring semester
ELEC 5033 Advanced Electromagnetic Fields
ELEC 5134 Introduction to Microwave Circuit Design

Courses offered occasionally
ELEC 5433 Applications and Fundamentals of Plasmas
ELEC 5335 Graduate Electromagnetics
ELEC 5373 Optical Engineering

(d) Computer Engineering and Embedded System Design
Courses offered
ELEC 5511 Hardware-Software Interface
ELEC 5727 Machine Vision Systems
ELEC 5678 Introduction to Quantum Computing (fall)
ELEC 5679 Quantum Computing Algorithms (spring)
ELEC 5680 Quantum Computing Technology (fall)
ELEC 5152 Introduction to Intelligent Transportation Systems
ELEC 5804 Printed Circuit Board Design
ELEC 5531 Introduction to Deep Learning: Building with PyTorch

(e) **Energy and Power Systems**:

Courses offered every Fall semester
ELEC 5164 Electric Machines and Drive Systems
ELEC 5174 Power Electronic Systems
ELEC 5444 Power Systems Laboratory
ELEC 5152 Introduction to Intelligent Transportation Systems

Courses offered every Spring semester
ELEC 5184 Power Systems Analysis
ELEC 5170 Electric Machines and Drive Systems *Labs*
ELEC 5164 Electric and Hybrid Vehicle Powertrains
ELEC 5474 Power Electronics Laboratory

Courses offered every other Fall semester
ELEC 5194 Power Systems Operation and Control

Courses offered every other Spring semester
ELEC 5755 Grid Integration of Renewable Energy
ELEC 5294 Advanced Power Electronics
ELEC 5710 Advanced Electric Drive Systems
ELEC 5725 Advanced Electric Machinery

Courses offered occasionally
ELEC 5774 Power Systems Dynamics and Protection
ELEC 5806 Substation Energy Design
ELEC 5800 Electric Machinery a Hands on Approach

Selected Math Courses
ELEC 5210 Optimization Methods in Engineering
ELEC 5220 Methods of Engineering Analysis
ELEC 5230 Advanced Linear Systems

Remark: The EE department occasionally offers special topics courses, numbered EE58xx, which may count towards the satisfaction of the M.S.E.E.major/minor area requirements, as advised by the candidate's major advisor.

APPENDIX 2

FACULTY ADVISORS AND AREAS OF SPECIALTY

2.1 Full Time Faculty

DeLeon, Phillip, Ph.D., Electrical Engineering, University of Colorado at Boulder.
Digital signal processing (DSP) for audio and speech applications, machine learning including deep learning, time-frequency signal analysis, and embedded systems and mobile application programming.

Fardi, Hamid, Ph.D. Electrical Engineering, University of Colorado at Boulder.
Solid State Electronics: device modeling, VLSI, measurements and characterization.

Garrido, Jacqueline, Ph.D., Electrical Engineering, University of California, Riverside
Renewable energy, energy efficiency, machine learning, intelligent transportation systems, controls, computer vision.

Gedney, Stephen, Ph.D. Electrical Engineering, University of Illinois at Urbana-Champaign
Computational electromagnetics, electromagnetic scattering, antenna modeling and design, magnetic signature modeling, microwave and millimeter wave circuit modeling and design.

Golkowski, Mark, Ph.D. Electrical Engineering, Stanford University.
Electromagnetic waves, interactions of fields and matter, plasma discharges, waves in plasmas, phenomena of the ionosphere and magnetosphere.

Lei, Tim C., Ph.D., Electrical Engineering, University of Michigan, Ann Arbor.
Ultrafast and nonlinear optics, biophotonics, advanced spectroscopic and microscopic techniques for biomedical applications, disease diagnostics and treatments with optical techniques

Mancilla-David, Fernando A., Ph.D. Electrical Engineering, University of Wisconsin Madison.
Power system engineering, advanced power electronics.

Park, Jae-Do, Ph.D., Electrical Engineering, Pennsylvania State University.
Electric machine modeling and control, drive system design, energy conversion system applications.

Parada-Mayorga, Alejandro, Ph.D., Electrical and Electronics Engineering, University of Delaware
Mathematical foundations of information processing and learning, signal processing on manifolds and graphs, compressed sensing, compressive spectral imaging.

Radenkovic, Miloje, Ph.D. Electrical Engineering, Belgrade University, Yugoslavia.
Systems and Control Theory: robust control systems, stochastic control and system identification, adaptive systems in control and signal processing, control of large-scale systems, intelligent control.

Sahai, Aakash Ph.D. Electrical Engineering, Duke University.
Electromagnetics, plasma physics, high energy physics, particle accelerators, numerical simulations.

Appendix 3

Rubrics for Scoring PhD Comprehensive Exam and Annual Reviews

These Rubrics are to serve as a guide for the PhD Comprehensive Examination, Subsequent Annual Reviews, and the Final Defense. Scoring should be between 1 – 4, with 4 being Exceptional, and 1 being Unsatisfactory. Each committee member should provide an independent score. The average score of all committee members is to be entered on the PhD students checklist.

	Excellent 4	Good 3	Satisfactory 2	Unsatisfactory 1
Quality of Writing	Written in clear English and using precise technical language. Clearly states objectives. Provides motivation & background with proper referencing throughout. Clearly presents ideas and concepts. Excellent validation of work. Draws clear conclusions. Figures and graphics of high quality and well integrated with text.	Written in good English. States objectives. Provides motivation & background with references. Clearly presents ideas and concepts. Validates work. Draws clear conclusions. Appropriate use of figures and graphics.	Written in understandable English. States objectives. Provides motivation & background (with some references). Presents ideas and concepts. Validates work. Draws conclusions. Organization, presentation and/or figures could use improvement.	Written in poor English. Objectives are not clear. Inadequate background or motivation. Inadequate presentation of ideas and concepts.
Quality of Oral Presentation	Clear, coherent, and motivational oral presentation. Good eye contact. Has sense for diversity of the audience and puts work in broader context. Well prepared and organized slides. Clearly states objectives. Clearly demonstrates objectives & draws conclusions. Excellent use of visual aids.	Good and coherent oral presentation. Good eye contact. Understands the audience. Well prepared presentation. Clearly states objectives. Demonstrates objectives and draws conclusions. Good use of visual aids.	Mostly coherent oral presentation. Sates objectives. Demonstrates objectives and draws conclusions. Use of visual aids but preparation and organization could use improvement.	Poor oral presentation. Disorganized presentation. Objectives are unclear. Visual aids is lacking or inadequate.
Ability to Field Technical Questions	Clear understanding of questions and their context. Coherently and succinctly provides answers to the understanding of audience with strong technical evidence backing response.	Understands questions and has a satisfactory understanding of their context. Coherently provides answers with sufficient technical evidence backing response.	Mostly understands questions. Has the ability to communicate answers to a majority of questions.	Often misunderstands questions. Poor ability to communicate a clear answer or solution to questions.
Level of Scholarship	Complete knowledge of technical field and previous work. Understands context of area of research with respect to other	Strong knowledge of technical field and previous work.	Mostly understands technical field and has some knowledge of previous work.	Shallow comprehension of the technical field or research area.

	research and broad contemporary issues.			
Ability to Perform Independent Research	Has the aptitude and ability to think independently evaluate approaches to find solutions to challenging problems. Exhibits creativity in thought and intellectual depth. Excellent ability to pose strong arguments in support of their solution methodologies. Excellent ability to design new experiments and develop novel ways to build evidence supporting arguments. Excellent ability to be critical of their own arguments. Complete knowledge of previous work.	Has the ability to think independently and discuss approaches to find solutions to existing problems. Exhibits creativity in thought. Ability to pose strong arguments in support of their solution methodologies. Good ability to design new experiments and develop ways to build evidence supporting arguments. Ability to be critical of their own arguments.	Some ability to think independently and pose approaches to find solutions to existing problems. Has some creativity in thought. Poses adequate arguments in support of their solution methodologies. Some ability to design new experiments and develop ways to build evidence supporting arguments.	Inability to independently contrive new solutions or approaches. Lacks coherence, confidence, and understanding of the theory previous work. Presents work that is not original. Lacks ability to pose strong arguments.