TO: The Faculty of the College of Engineering

FROM: School of Electrical and Computer Engineering of the College of Engineering

RE: New Graduate Course, ECE 60420 Radio Frequency Integrated Circuits

The faculty of the School of Electrical and Computer Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ECE 60420 Radio Frequency Integrated Circuits
Sem. 1, Lecture 3, Cr. 3.

Prerequisite by Topic: Solid-state devices, Electromagnetics and analog and digital circuits

Description: This course aims at analysis and design of CMOS integrated radio frequency (RF), microwave and mm-wave circuits. Various modules of an RF transceiver are discussed including, low noise amplifiers, mixers, oscillators, frequency synthesizers and power amplifiers. A term project on design of an RF to mm-wave module is also required.

Reason: With the proliferation of cell phones and other wireless mobile devices, and the ever-increasing performance requirement, analysis, design and low-cost implementation of radio frequency, microwave and mm-wave integrated circuits have become important topics for graduate studies in electrical engineering. Almost every respected graduate program in devices and circuits offers such a course at an advanced level. Students who may be interested in this course should have a background in applied electromagnetic, analog and digital circuits and solid-state devices. The appropriate level for this course is therefore a 600 level. The targeted audience is 2nd and 3rd year graduate students in vlsi and circuit, microelectronic and nanotechnology and field and optics who have completed the pre-requisites and are planning to widen their knowledge base in this area. The course goes through many topics in a very fast pace to introduce students to all the important topics. Students choose one of the topics for their term project to go deeper and gain a much better understanding of their topic. For their term project, students must do an in-depth literature search, analysis and design and simulation and optimization of their topic.

Michael R Melloch

Michael R. Melloch, Associate Head
School of Electrical and Computer Engineering

Office of the Registrar
FORM 40G REV. 4/13

PURDUE UNIVERSITY
REQUEST FOR ADDITION, EXPIRATION, OR REVISION OF A GRADUATE COURSE
(50000-60000 LEVEL)

DEPARTMENT: Electrical and Computer Engineering EFFECTIVE SESSION: Spring 2016

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

- [x] 1. New course with supporting documents (complete proposal form)
- [ ] 2. Add existing course offered at another campus
- [ ] 3. Expiration of a course
- [ ] 4. Change in course number
- [ ] 5. Change in course title
- [ ] 6. Change in course credit/type
- [ ] 7. Change in course attributes
- [ ] 8. Change in instructional hours
- [ ] 9. Change in course description
- [ ] 10. Change in course requisites
- [ ] 11. Change in semesters offered
- [ ] 12. Transfer from one department to another

PROPOSED:		EXISTING:	
Subject Abbreviation	ECE	Subject Abbreviation	
Course Number	60420	Course Number	
Long Title	Radio Frequency Integrated Circuits		
Short Title	Radio Frequency Integrated Cir		

Abbreviated title will be entered by the Office of the Registrar if omitted. (30 CHARACTERS ONLY)

TERMS OFFERED (Check All That Apply): [x] Fall [ ] Spring [ ] Summer

CAMPUS(ES) INVOLVED:
- [ ] Calumet
- [ ] Cont Ed
- [ ] Ft. Wayne
- [ ] Indianapolis
- [ ] N. Central
- [ ] Tech Statewide
- [x] W. Lafayette

CREDIT TYPE
1. Fixed Credit: Cr. Hrs. 3
2. Variable Credit Range: Minimum Cr. Hrs ____ (Check One) To [ ] Or [ ] Maximum Cr. Hrs ____
3. Equivalent Credit: Yes [ ] No [x]
4. Thesis Credit: Yes [ ] No [x]

COURSE ATTRIBUTES: Check All That Apply
1. Pass/Not Pass Only [ ]
2. Satisfactory/Unsatisfactory Only [ ]
3. Repeatable [ ]
   Maximum Repeatable Credit: [ ]
4. Credit by Examination [ ]
5. Fees [ ] Coop [ ] Lab [ ] Rate Request
   Include comment to explain fee
6. Registration Approval Type: Department [ ] Instructor [ ]
7. Variable Title [ ]
8. Honors [ ]
9. Full Time Privilege [ ]
10. Off Campus Experience [ ]

Schedule Type	Minutes Per Mtg	Meetings Per Week	Weeks Offered	% of Credit Allocated
Lecture	3	50	16	100
Recitation				
Presentation				
Laboratory				
Lab Prep				
Studio				
Distance				
Clinic				
Experiential				
Research				
Ind. Study				
Pract/Observ				

Cross-Listed Courses

COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):

This course aims at analysis and design of CMOS integrated radio frequency (RF), microwave and mm-wave circuits. Various modules of an RF transceiver are discussed including, low noise amplifiers, mixers, oscillators, frequency synthesizers and power amplifiers. A term project on design of an RF to mm-wave module is also required.

*COURSE LEARNING OUTCOMES:

o Knowledge of various wireless standards, modulation techniques and CMOS technology (a)
o Knowledge of matching network, transmission line effects, Scattering parameters (a)
o Analysis and Design of CMOS low noise amplifiers from RF to mm-wave frequencies (a, c)

Calumet Department Head	Date	Calumet School Dean	Date	Calumet Director of Graduate Studies	Date
Fort Wayne Department Head	Date	Fort Wayne School Dean	Date	Fort Wayne Director of Graduate Studies	Date
Indianapolis Department Head	Date	Indianapolis School Dean	Date	IUPUI Associate Dean for Graduate Education	Date
North Central Department Head	Date	North Central School Dean	Date	North Central Director of Graduate Studies	Date
West Lafayette Department Head	11/4/15 Date	West Lafayette College/School Dean	Date	Date Approved by Graduate Council	Date
Graduate Area Committee Convener	Date	Graduate Dean	Date	Graduate Council Secretary	Date
				West Lafayette Registrar	Date

OFFICE OF THE REGISTRAR

Supporting Document to the Form 40G
for a New Graduate Course

To: Purdue University Graduate Council

From: Faculty Member: Saeed Mohammadi

Department: Electrical and Computer Engineering

Campus: West Lafayette

Date:

Subject: Proposal for New Graduate Course

Contact for information if questions arise:
Name: Matt Golden
Phone: 494-3374
Email: goldenm@purdue.edu
Address: EE Building, Room 135

Course Subject Abbreviation and Number: ECE 60420

Course Title: Radio Frequency Integrated Circuits

Course Description:
This course aims at analysis and design of CMOS integrated radio frequency (RF), microwave and mm-wave circuits. Various modules of an RF transceiver are discussed including, low noise amplifiers, mixers, oscillators, frequency synthesizers and power amplifiers. A term project on design of an RF to mm-wave module is also required.

Semesters Offered:
For the benefit of graduate student plan of study development, how frequently will this prototype be offered? Which semesters?
Fall Odd Years

A. Justification for the Course:

With the proliferation of cell phones and other wireless mobile devices, and the ever-increasing performance requirement, analysis, design and low-cost implementation of radio frequency, microwave and mm-wave integrated circuits

have become important topics for graduate studies in electrical engineering. Almost every respected graduate program in devices and circuits offers such a course at an advanced level. Students who may be interested in this course should have a background in applied electromagnetic, analog and digital circuits and solid-state devices. The appropriate level for this course is therefore a 600 level. The targeted audience is 2nd and 3rd year graduate students in vlsi and circuit, microelectronic and nanotechnology and field and optics who have completed the pre-requisites and are planning to widen their knowledge base in this area. The course goes through many topics in a very fast pace to introduce students to all the important topics. Students choose one of the topics for their term project to go deeper and gain a much better understanding of their topic. For their term project, students must do an in-depth literature search, analysis and design and simulation and optimization of their topic.

- Anticipated enrollment
  - Undergraduate 0
  - Graduate 20-25

B. Learning Outcomes and Method of Evaluation or Assessment:

ECE Graduate Learning Outcomes:

a. Knowledge and Scholarship (thesis/non-thesis)
b. Communication (thesis/non-thesis)
c. Critical Thinking (thesis/non-thesis)
d. Ethical and Responsible Research (thesis) or Professional and Ethical Responsibility (non-thesis)

- List Learning Objectives for this course and map each Learning Objective to one or more of the ECE Learning Outcomes (a-d, listed above):

  - Knowledge of various wireless standards, modulation techniques and CMOS technology (a)

  - Knowledge of matching network, transmission line effects, Scattering parameters (a)

  - Analysis and Design of CMOS low noise amplifiers from RF to mm-wave frequencies (a, c)

  - Analysis and Design of CMOS mixers from RF to mm-wave frequencies (a, c)

- Analysis and Design of CMOS oscillators and frequency synthesizers from RF to mm-wave frequencies (a, c)
- Analysis and Design of CMOS power amplifiers from RF to mm-wave frequencies (a, c)
- Completing a term project focusing on analysis, design, simulation and optimization of one of the RF modules or an entire transceiver (a, b, c, d)

- Methods of Instruction
  - Lecture
- Will/can this course be offered via Distance Learning?
  - The course will not be offered via Distance Learning though it could be if necessary.
- Grading Criteria

  Grading criteria (select from checklist); include a statement describing the criteria that will be used to assess students and how the final grade will be determined. Add and delete rows as needed.

  - Two midterm exams
  - A term project focusing on design and simulation
  - Homework including simulation homework
  - attendance/participation

  ► Describe the criteria that will be used to assess students and how the final grade will be determined:

  Students will be assessed based on successful completion of their term project as well as demonstrating ability to perform analysis and design of RF circuits measured through homework and exams.

C. Prerequisite(s):

List prerequisites and/or experiences/background required. If no prerequisites are indicated, provide an explanation for their absence. Add bullets as needed.

- Graduate Standing or Consent of Instructor

- Prerequisite by Topic: Solid-state devices, Electromagnetics and analog and digital circuits.

D. Course Instructor(s):

Provide the name, rank, and department/program affiliation of the instructor(s). Is the instructor currently a member of the Graduate Faculty? (If the answer is no, indicate when it is expected that a request will be submitted.) Add rows as needed.

Name	Rank	Dept.	Graduate Faculty or expected date
Saeed Mohammadi	Associate Professor	ECEN	Yes

E. Course Outline:

Provide an outline of topics to be covered and indicate the relative amount of time or emphasis devoted to each topic. If laboratory of field experiences are used to supplement a lecture course, explain the value of the experience(s) to enhance the quality of the course and student learning. For special topics courses, include a sample outline of a course that would be offered under the proposed course. **(This information must be listed and may be copied from syllabus).**

Weeks	Principal Topics
Week 1:	RF front-end architectures and modulation techniques
Week 2:	Active/passive devices and CMOS technology
Week 3:	Distributed elements, S-parameters and Smith Chart
Week 4:	Understanding Noise in RF systems
Week 5:	Linearity of RF devices and circuits
Week 6:	Narrowband and wideband amplifier designs
Week 7:	Low Noise Amplifiers
Week 8	Review and Midterm 1
Week 9:	RF Mixers
Week 10-11:	RF Power amplifiers

Week 12-13:	Oscillators, frequency synthesizers and Phase Noise
Week 14:	Review and Midterm 2 (Nov. 24th)
Week 15:	Project presentations
Week 16:	Course summary and conclusion

F. Reading List (including course text):

A primary reading list or bibliography should be limited to material the students will be required to read in order to successfully complete the course. It should not be a compilation of general reference material.

A secondary reading list or bibliography should include material students may use as background information.

- Primary Reading List
  - The Design of CMOS Radio Frequency Integrated Circuit (Tom Lee), 2nd edition, Cambridge Press
  - Required Research Papers on various topics

- Secondary Reading List
  - Analysis and Design of Analog Integrated Circuits (Gray, Hurst, Lewis, Meyer) 5th edition, Wiley
  - Microwave Engineering (Pozar), 2nd edition, Wiley
  - Multi-GHz frequency Synthesis & Divisions (Rategh, Lee), Kluwer Academic
  - Architecture for RF Frequency Synthesizer (Vaucher), Kluwer Academic
  - RF Power Amplifiers for Wireless Communications (Cripps) 2nd edition, Artech House

G. Library Resources

Describe any library resources that are currently available or the resources needed to support this proposed course.

H. Course Syllabus

(While not a necessary component of this supporting document, an example of a course syllabus is available, for information, by clicking on the link below, which goes to the *Graduate School's Policies and Procedures Manual for Administering Graduate Student Program.*
See Appendix K.
http://www.purdue.edu/gradschool/faculty/documents/Graduate_School_Policies_and_Procedures_Manual.pdf