DEPARTMENT OF ELECTRICAL &
COMPUTER ENGINEERING

SCREENING EXAM MANUAL

UNIVERSITY OF CALIFORNIA
SANTA BARBARA

(UPDATED 8/17/17)

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I. INTRODUCTION

The purpose of the Ph.D. Screening Examination (henceforth, the Exam) is to screen candidates for continuation in the doctoral program. This exam is **not** required for admission to the Ph.D. program; however, to remain in the Ph.D. program, all students are required to pass the exam, which is normally given twice a year at the beginning of Fall and Spring quarters.

Students should plan for this exam immediately after entering the program. Rules for taking the exam are as follows:

(1) a student who entered the Ph.D. program, as a holder of an M.S. degree in Electrical and/or Computer Engineering must pass the exam no later than the second time it is offered following matriculation at UCSB;

(2) a student who entered the Ph.D. program without an M.S. degree in Electrical and/or Computer Engineering must pass the exam no later than the first time it is offered after the first occurrence of any of the following conditions:

(a) completion of all M.S. requirements other than the Comprehensive Examination;
(b) completion of 42 units of course work in the M.S. program; or
(c) the elapse of two years from date of matriculation in the M.S. program.

(3) students must have a minimum Grade Point Average of 3.3 to qualify to take the Exam. Students having a GPA of less than 3.3 at the time that they are required to take the Exam shall be considered to have failed the Exam. This failure will be counted as one of their allowed attempts at the Exam.

"Part-time" and other graduate students for whom this rule (1) or (2) represents undue hardship may petition the Department Graduate Advisor for an extension of time. The petition must be submitted no later than two months before the examination and must be endorsed by the student's Faculty Advisor.

If a student fails the first attempt at the examination, s/he must repeat the examination the next time that it is offered. A student is allowed a maximum of two attempts at the Ph.D. Screening Examination.

In the case when a student reaches the maximum number of allowed attempts at the examination without having passed it, the eligible ECE Faculty will vote on whether or not to remove the student from the Ph.D. program. A student who fails to show up for part or all of the examination is considered to have taken the examination and failed it.

Any petition or appeal regarding:

- the result of the examination, or;
- a subsequent examination attempt, or;
- the removal from the Ph.D. program

must be made before the end of the quarter in which the student failed the examination.

A student's choice of major examination area should conform to their area of interest as indicated by the choice of research advisor and Ph.D. committee. Exceptions require the approval of the student's Ph.D. committee and the Department Graduate Advisor. A student who, after passing the screening examination, chooses a committee not conforming the major area of the examination must either petition the Department Graduate Advisor for approval, or, at the earliest available opportunity, retake the Ph.D. screening examination with the choice of major conforming to the research advisor's area of interest. The Department Graduate Advisor must be informed of the intended change in the area of specialization before dissertation research commences in the new area. Students who have been removed from the Ph.D. program are not eligible for additional attempts at the screening examination by declaring a change of specialization.

The Screening Examination consists five (three in a chosen major area and two in a chosen minor area) one-to-one oral exams and is administered by the Graduate Examination Committee (GEC) of the ECE faculty. To pass the Exam, a student must: a) pass the oral components of the Exam; or b) pass by simple majority vote of the eligible ECE faculty.

There is no grade of "conditional pass" or "pass at M.S. level only," since the examination is intended for doctoral students. However, Plan II M.S. students who are serious about pursuing the Ph.D. may take the exam and, if passed, substitute it for the M.S. Comprehensive Examination. Each student who has taken the exam will receive a written notification, from the GEC chairperson, about the final faculty decision, as soon as practical after this decision has been made. However, since letters take several days to arrive, students are encouraged to talk with their faculty advisors soon after the completion of the exam. The results are expected to be available after 5:30 pm on the day of the oral exam.

II. THE EXAM FORMAT

Each student must take an oral major examination in the area of his/her intended specialization. Major examinations are given in the following five standard areas:

- **Computer Engineering**
- **Control Systems**
- **Signal Processing**
- **Communication**
- **Electronics and Photonics**

Each student will be examined for 20 minutes by 3 professors in his/her major area.

An oral minor exam will be required in any one of the five major exam areas listed above.
This oral minor exam will be given by at least two professors from the minor area.

A student intending to take the Ph.D. Screening Examination must complete an application. Application forms are available in the ECE Graduate Student Office (Building 697, Room 101 – this is across the way from the main ECE Student Office).

III. CHANGE OF SPECIALIZATION

If the student, after passing the Ph.D. Screening Examination, changes his or her area of specialization as indicated by the major examination area to an area in which he or she was not examined in the Screening Examination, the student must take and pass another oral examination in the new major area of specialization. (A student who has failed the exam twice, and who has therefore been removed from the Graduate Program, is not entitled to another exam by declaring a change in the area of specialization.) This second exam will also be administered by the GEC, who will decide the type of examination to be given and its schedule. The student must notify the chairperson of the GEC of the decision to change the area of specialization before beginning dissertation research in the new area.

IV. SYLLABUS FOR THE EXAM

The oral examinations assume a reasonably mature knowledge of course materials that are usually taught in undergraduate or beginning graduate courses. To delineate further the scope of the subject matter for the exam, a list of topics together with suggested references is provided below for each of the standard major and minor areas. The references cited are chosen for their convenience and availability. No claim is made that they are the best or most appropriate references. There are in all cases many other textbooks, which treat the material at the appropriate level. It is recommended that a student reviewing the material use the text with which he or she is most familiar (or the one most readily available), after assuring himself or herself that coverage of the topics in question is at a level comparable to that of the cited texts. It is anticipated that a thorough review can be made with the texts the students have used in their own relevant courses, with an occasional reference to other texts to achieve full coverage.

Many of the suggested references can be found in the UCSB Library (some may be at the Reserve Book Room under the relevant course number).

MAJOR AND MINOR EXAMS

A. COMPUTER ENGINEERING

The examination in Computer Engineering (CE) is based on core courses found in advanced undergraduate and beginning graduate courses of most computer science/engineering programs. As in other areas, the screening exam in Computer Engineering is not meant to duplicate the final exams of the various ECE courses. Rather, the focus of this exam is on the depth of understanding, ability to relate ideas from different courses, and the student's approach to solving open-ended or ill-defined problems using the knowledge gained from coursework.

Since fall quarter 2005, the Computer Engineering exam has had 9 areas from which both major and minor students select their exam topics. The following is a list of these 9 areas and a list of the courses on which each area is based.

1) Digital Design Fundamentals (ECE 15A, ECE 152A)
2) Computer Architecture (ECE 15B, ECE 154)
3) Data Structures (CS 130A, CS 130B)
4) Compilers and Operating Systems (CS 160, CS 170)
5) VLSI and CMOS Design (ECE 124A, ECE 124D)
6) Design Methodologies and Automation (ECE 152B, ECE 156A, ECE 156B)
7) Computer Networks and Distributed Systems (ECE 151, ECE 155A, ECE 155B)
8) Hardware/Software interface (ECE 153A, ECE 153B)
9) Multimedia Systems (CS 165B, ECE/CS 181B, ECE 160)

A student wishing to take a CE screening exam chooses one of the following options:

I. The student takes both major and minor exams in CE by choosing 5 of these 9 CE areas.
II. The student takes a CE major exam by choosing any 3 out of the 9 CE areas and takes a minor outside of CE.
III. The student takes a major exam outside of CE and takes a minor exam in CE by choosing any 2 of these 9 CE areas.

The material covered in each of the 9 areas is based directly on the current syllabi and textbooks of the UCSB courses in that area. The current ECE course syllabi are available at: http://www.ece.ucsb.edu/current_courses.shtml.

B. CONTROL SYSTEMS

The examination in Control Systems is based on curricular material found in advanced undergraduate and beginning graduate courses in control and systems at most electrical engineering departments. The relevant courses at UCSB are the following:

1) Fundamentals of signals, systems, and random processes: ECE 130A, B, C; ECE 140
2) Analog and digital control: ECE 147A and B
3) Modern linear systems: ECE 230A and B

Majors will be examined in each of these three areas, and minors in areas 2 and 3. The emphasis in these examinations is to test your understanding of the fundamental concepts and techniques, and your ability to apply these to solve problems.

The course descriptions and texts for these courses provide sources for the topics covered in them. At present the texts are:

ECE 130AB A.V. Oppenheim and A.S. Willsky with I.T. Young, 1996, *Signals and Systems,* 2nd ed., Prentice-Hall.
ECE 130C G. Strang, 2006, *Linear Algebra and Its Applications*, 4th ed., Brooks Cole.
ECE 140 A. Papoulis and S. U. Pillai, 2002, *Probability, Random Variables, and Stochastic Processes*, 4th ed., McGraw-Hill.
ECE 147A G. Franklin, J.D. Powell and A. Amani-Naeini, 2005, *Feedback Control of Dynamic Systems*, 5th ed., Prentice Hall.
ECE 147B G. Franklin, J.D. Powell, and M. Workman, 1998, *Digital Control of Dynamic Systems*, 3rd ed., Prentice Hall.
ECE 230AB C.T. Chen, 1998, *Linear Systems Theory and Design,* 3rd ed., Oxford University Press.

Sources for this material include standard texts on linear systems, control, and filtering:

1. B.D.O Anderson and J.B. Moore, 1990, *Optimal Control,* Prentice-Hall.
2. B.D.O. Anderson and J.B. Moore, 2005, *Optimal Filtering*, Dover Publications.
3. K. Astrom and B. Wittenmark, 1997, *Computer Controlled Systems*, 3rd ed., Prentice Hall.
4. C.T. Chen, 1998, *Linear Systems Theory and Design,* 3rd ed., Oxford University Press.
5. T. Kailath, 1980, *Linear Systems*, Prentice-Hall.
6. H. Kwakernaak and R. Sivan, 1972, *Linear Optimal Control Systems,* Wiley.
7. W.M. Wonham, 1985, *Linear Multivariable Control: A Geometric Approach,* 3rd ed., Springer.

C. SIGNAL PROCESSING

The examination in Signal Processing is based on curricular material typically found in advanced undergraduate and beginning graduate courses of most electrical engineering departments.

Topics

1) Basic Signals and Systems-Representation of signals; singularity functions; system modeling with differential and difference equations; linear time-invariant systems; convolution; zero input response; complete response; transient and steady-state response; multiple input/output systems; signals flow graphs. Transform Methods-Fourier and Laplace transforms; z-transforms; discrete Fourier transform; transfer functions; power and energy spectra. (Related courses at UCSB are ECE 130ABC.)

2) Digital Signal Processing-Sampling of analog signals; discrete-time signals and systems; use of z-transforms; flow graph and matrix representation of digital networks; FIR and IIR

digital filters; filter structures; filter design; bilinear transform; Applications of digital signal processing. (Related courses at UCSB are ECE 158 and ECE 258A&B.)

3) Basic probability theory and random processes. (Related courses at UCSB are ECE 139, ECE 140 & ECE 235.)

Majors will be examined in all three topics and the minors in the first two topics.

Suggested References:

A.V. Oppenheim and R.W. Schafer, 1999, *Discrete-time Signal Processing*, 2^{nd} ed., Prentice-Hall.

A.V. Oppenheim and A.S. Willsky, 1997, *Signals and Systems*, 2^{nd} ed., Prentice-Hall.

A. Papoulis and S. U. Pillai, 2002, *Probability, Random Variables, and Stochastic Processes*, 4^{th} ed., McGraw-Hill.

S.K. Mitra, 2006, *Digital Signal Processing*, 3^{rd} ed., McGraw-Hill.

G. Strang, 2006, *Linear Algebra and Its Applications*, 4th ed., Brooks Cole.

D. COMMUNICATIONS

The examination in Communication is based on curricular material typically found in advanced undergraduate and beginning graduate courses of most electrical engineering departments.

Topics

1) Analog Communications: Lowpass and bandpass signals and filtering. Modeling of additive noise. Generation and demodulation of AM, SSB, DSB and FM signals. Performance of amplitude and angle modulation techniques. Spectra of modulated signals. (Related UCSB courses: ECE 146A.)

2) Digital Communications: Sampling, quantization and analog-to-digital conversion. PCM, DPCM and delta modulation. Bit error-rate in digital transmission. Role of bandwidth, power and noise in communication system performance. Geometric signal models. Correlators and matched filters. Intersymbol interference, digital carrier modulation techniques. (Related UCSB courses: ECE 146B)

3) Basic probability theory and random processes. (Related courses at UCSB are ECE 139 & ECE 140)

Majors will be examined in all three topics and the minors in the first two topics.

Suggested References:

Roy D. Yates and David J. Goodman, 2005, *Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers,* 2^{nd} ed., Wiley.

Sheldon Ross, 2005, *A First Course in Probability,* 7th ed., Prentice-Hall.

A. Papoulis and S. U. Pillai, 2002, *Probability, Random Variables, and Stochastic Processes*, 4th ed., McGraw-Hill.

P.Z. Peebles, Jr., 2001, *Probability, Random Variables, and Random Signal Principles*, 4th ed., McGraw-Hill.

John G. Proakis and Masoud Salehi, 2002, *Communication Systems Engineering*, 2nd ed., Prentice Hall.

S. Haykin, 2001, *Communications Systems*, 4th ed., Wiley.

F. Stremler, 1990, *Introduction to Communication Systems*, 3rd ed., Addison-Wesley.

E. ELECTRONICS AND PHOTONICS

Areas and Topics:

Area A: Physics
- A1: Quantum Mechanics
- A2: Solid State Physics

Area B: Electromagnetic Fields and Waves
- B1: General E&M Theory
- B2: Guided Waves, and Radiation
  - (A re-arranged subset of the present WaveTech exams)

Area C: Devices
- C1: Electronic Devices
- C2: Photonic Devices
  - (A long-demanded broadening over what we have now)

Area D: Circuits
- D1: High-Speed Analog Circuits
- D2: Radio Frequency Communication Circuits and Systems

The E&P exam may be taken in three forms:

(1) Both Major and Minor in E&P (5 examinations)
(2) Major in E&P, Minor somewhere else (3 examinations)
(3) Minor in E&P, Major somewhere else (2 examinations)

To ensure breadth, the following selection constraints must be met:

(1) Combined Major/Minor:
All three of the areas A, B, and C must be represented by at least one exam each;

the remaining two exams may be chosen freely.

(2) Major only:
At least two of the four areas A, B, C, and D must be represented by at least one exam each;
the third exam may be chosen freely.

(3) Minor only:
Any two of the 7 exams may be chosen.

AREA A: PHYSICS

A1: Quantum Mechanics—Wave-particle duality. Wave packets. Uncertainty relations. Schroedinger equation. Expectation values. Eigenfunctions and eigenvalues. Harmonic oscillators and other simple bound states. Time-dependent superpositions of states. Scattering and tunneling. Angular momentum. Hydrogen atom.

A2: Solid State Physics—Crystal structure. Crystal diffraction. Reciprocal lattice. Brillouin zones. Lattice vibrations. Free-electron Fermi gas. Energy bands. Optical transitions in direct and indirect-gap semiconductors. Wave vectors. Bloch functions. Classification of solids. Electrons and holes in semiconductors. Equations of motion. Effective mass. Fermi statistics. Intrinsic and extrinsic semiconductors. Impurity levels. Quantum wells.

Suggested References:

1. A.P. French and E.F. Taylor, 1978, *An Introduction to Quantum Physics,* W.W. Norton; Chapters 1-5, 7-12; sub-area A1.
4) Herbert Kroemer, 1994, *Quantum Mechanics*, Prentice-Hall; Chapters 1 through 4: both levels. Chapter 7 (except Sec. 7.3), sub-area A1.
3. C. Kittel, 1976, *Introduction to Solid State Physics,* 6th ed. or 7th ed., Wiley,; Chapters l, 2, 4, 6-8; sub-area A2.
4. C. Kittel and H. Kroemer, 1980, *Thermal Physics,* 2nd ed. (not 1st!), Freeman; Chapters 11 & 13, plus material needed to get there (Chapters 1-3, 5, 6, 7); For sub-areas A2 and also C1 (see below).

AREA B: ELECTROMAGNETIC FIELDS AND WAVES

Area B of the exam is on electromagnetic theory and wave phenomena. A sound understanding of the underlying physical principles of electromagnetic fields and waves is essential to the researcher in high frequency electronics, optoelectronics, photonics and optics. The material covered in this exam is usually thought in undergraduate and first year graduate level courses in electrical engineering and physics. Exam questions will be selected to test the student's conceptual understanding of the electromagnetic theory and wave phenomena fundamentals, and his/her ability to apply this knowledge to solving new problems. Students should not memorize complicated formulae, with the exception of fundamental laws or principles, such as Maxwell's equations. The two topics examined in this area are:

B1: General Electromagnetic Theory

Maxwell's equations; wave equation; static, quasi-static and time varying fields; boundary conditions; plane waves; polarization; plane wave reflection and refraction; propagation in dielectric and conducting media; traveling waves, standing waves and resonance; vector and scalar potentials; temporal and time harmonic analysis; power and energy flow in electromagnetics.

B2: Guided Waves and Radiation

Transmission line theory; dielectric and metallic waveguides; waveguide modes and field patterns; phase and group velocity; cut-off, attenuation and dispersion; discontinuities in waveguides; wave propagation in periodic structures; principles of electromagnetic radiation; radiation from current distributions; antennas; antenna arrays; scalar diffraction theory.

Suggested references:

1. F. S. Crawford, Jr., 1968, *Waves, Berkeley Physics Course*, volume 3, McGraw-Hill,.

2. D. K. Cheng, 1989, *Field and Wave Electromagnetics*, 2nd ed., Addison-Wesley,.

3. S. Ramo, J. R. Whinnery, and T. Van Duzer, 1994, *Fields and Waves in Communication Electronics*, 3rd ed., Wiley.

4. C. A. Balanis, 2005, *Antenna Theory: Analysis and Design*, 3rd ed., Wiley.

AREA C: DEVICES

C1: Electronic Devices

Area C of the exam is on Electronic Devices and Photonic Devices.

Detailed below are the topics on which the candidate will be examined in the area of Electronic Devices. The aim of the examination is to ascertain whether the candidate has a sound understanding of Device Physics and Electronic Device Operation. The topics are:

Understanding E-k diagrams; Concepts of effective mass; Doping; Carrier Statistics; Concepts of mobility and velocity saturation; p-n junction and Schottky Barrier theory including calculating and sketching band diagrams, nature of current transport, derivation of the diode equation, conductance and capacitance of the junction; solar cell operation; bipolar transistor operation including calculating and sketching band diagrams, nature of current transport, derivation of collector, emitter and base current expressions, derivation of DC figures of merit, non-ideal behavior; JFET operation including calculating and sketching band diagrams, the gradual channel analysis; MOSFET operation including calculating and sketching band diagrams, the gradual channel analysis.

The questions will try to gauge the understanding of the student and not test the ability to merely memorize formulae.

Suggested References;

1. Ben G. Streetman, 2005, *Solid State Electronic Devices*, 6th ed., Prentice Hall.
2. Richard S. Muller and Theodore I. Kamins, 2002, *Device Electronics for Integrated Circuits*, 3rd ed., Wiley.
3. S.M. Sze, 2001, *Semiconductor Devices Physics and Technology*, 2nd ed., Wiley.
4. C. Kittel and H. Kroemer, 1980, *Thermal Physics,* 2nd ed. (not 1st!), Freeman; Chapters 11 & 13, plus material needed to get there (Chapters 1-3, 5, 6, 7); Also for sub-area A2 (see above).

C2: Photonic Devices

This focus area includes the design and properties of optical and optoelectronic devices, in which photons are generated, transported, modulated, or detected.

Topics:
Semiconductor heterostructures; PiN diodes; Photodetectors; Solar Cells; LEDs; gas, solid-state and semiconductor lasers; optical modulators; optical waveguides; integrated optics; nonlinear optics

Suggested References:
1. L. Solymar and Walsh, 1998, *Lectures on the Electrical Properties of Materials*, 6th ed., Oxford; Chapters 12 and 13
2. A. Yariv, 1997, *Optical Electronics in Modern Communications*, 5th ed., Oxford University Press.
3. J. T. Verdeyen, 1995, *Laser Electronics*, 3rd ed., Prentice Hall,
4. P. Bhattacharya, 1996, *Semiconductor Optoelectronic Devices*, 2nd ed., Prentice Hall.
5. L. Coldren and S. Corzine, 1995, *Diode Lasers and Photonic Integrated Circuits,* Wiley; Chapters 1-3 and Appendices 1-6
5) B. Saleh and M. Teich, 1991, *Fundamentals of Photonics*, Wiley.

AREA D: Circuits

D1: High-Speed Analog Circuits

Philosophy:
Analog circuit designers implement circuits with hundreds to thousands of transistors. The competent circuit designer must therefore have a comprehensive and intimate understanding of the fundamental component transistor gain stages from which larger systems are constructed. The competent analog designer can analyze the simple transistor stages extremely rapidly.

Of even greater importance, a circuit designer of ability consistent with the Ph.D. program is able to invent - and to examine critically - novel circuit designs, which address the evolving needs of the electrical engineering community. The candidate must therefore be able to quickly analyze unfamiliar circuits - perhaps using unfamiliar devices - using the fundamental principles of circuit analysis and of active device modeling. The following topics are therefore of major importance;

Fundamentals of Electrical Circuit Analysis

The candidate is expected to be able to efficiently and rapidly solve linear electrical networks, whether in the transient time domain or the sinusoidal steady state. Solution of circuits by the canonical nodal analysis method. Superposition. Thevenin and Norton methods. Transfer functions. Complex frequency, the S-plane, real and complex poles and
zeros, resonance and exponential decay. Impulse and step responses, convolution. Bode plots. The recommended reference for this material is "Electric Circuit Analysis", Third Edition, Authors Johnson, Johnson, Hilburn, and Scott, Publisher Prentice-Hall, 1997. As this is a Sophomore-level circuits text, it is to be emphasized that the candidate must be intimately and comprehensively familiar with the material within. Specifically, during the course of the exam, it is likely that there will be encountered circuits of a complexity such that 2 simultaneous equations must be identified, written, and solved.

Transistor Analog Circuit Analysis
The candidate must be able to analyze unfamiliar circuits containing active devices, and must therefore understand the physics and equivalent circuit models of semiconductor devices. The recommended reference for this material is "Analysis and Design of Analog Integrated Circuits", Fourth Edition, Authors Gray, Hurst, Lewis and Meyer, Publisher J. Wiley, 2001. This material is covered in undergraduate and first-year graduate courses. Specific chapters are cited in parenthesis. The candidate must be intimately familiar with the physics and equivalent circuit models of bipolar transistors, MOSFETs, and diodes (Ch. 1). The candidate should also be very familiar with single-transistor stages (Ch. 3), active loads (Ch. 4), transistor amplifier frequency response (Ch. 7) and with feedback circuits (Chs. 8 and 9).

Microwave Analog Circuits

The candidate should be familiar with models for and applications of high performance devices at microwave frequencies. Familiarity with the use of equivalent circuit models and S parameter methods is expected along with the inclusion of transmission line elements into active circuits, impedance matching and tuned amplifier design.

Suggested Reference:

Razavi, Behzad, *Fundamentals of Microelectronics, 2nd Edition,* Prentice Hall (ISBN-13: 978-1118156322; ISBN-10: 1118156323).

Razavi, Behzad, *Design of Analog CMOS Integrated Circuits, 1st Edition,* McGraw-Hill. (ISBN-13: 978-0072380323; ISBN-10: 0072380322)

D2: Radio Frequency Communication Circuits and Systems

Philosophy:
Radio-frequency integrated circuit (RFIC) designers must command a range of disciplines to understand how fundamental device physics in planar integrated circuits, RF circuit design, and signal processing techniques can address modern interference-limited wireless communication. The competent RFIC designer must therefore have a comprehensive understanding of the relationship between transistor physics, the generation of noise and distortion in transistors and circuits, and the impact on modulated signal waveforms. A Ph.D. candidate should be able to critically examine unfamiliar circuits using fundamental principles

of RF and microwave circuit analysis and device modeling to understand the impact on the evolving needs of the RF systems. The recommended reference for this material is "*Radio-Frequency Integrated Circuits and Systems*", First Edition, Author H. Darabi, Publisher Cambridge University Press, 2015.

Fundamentals of High-Frequency Circuit Analysis and Two-port Networks

The candidate is expected to understand lumped-element and microwave circuit analysis regimes. The candidate should be able to rapidly and efficiently solve resonant electrical networks using equivalent circuit models and two-port network analysis. The candidate should be fluent with high-frequency transistor models and also with modeling of passive, planar electromagnetic structures such as inductors, capacitors, and transmission line structures (Ch. 1). The candidate should be able to explain the operation of basic microwave components such as power combiners and splitters, couplers, and baluns.

Low-noise Amplifier Circuitry

The candidate must be capable to demonstrate optimal gain and noise matching of transistors in amplifier circuits. The candidate must be intimately familiar with noise (Ch. 4) and distortion analysis (Ch. 5) including the generation of intermodulation distortion. The candidate should also be familiar with noise and distortion analysis of single and multiple transistor stages in the presence of feedback networks (Ch. 6). The candidate will be able to explain the receiver operation and filtering requirements for interference and noise (Ch. 10).

Frequency Conversion and Oscillators

The candidate should be familiar with models for mixers and frequency multipliers and applications of transistors to passive and active circuitry (Ch. 7). Additionally, the operation of oscillators should be readily anaylyzed (Ch. 8). The candidate will understand the impact of oscillator phase noise on RF receivers.

Power Amplifier Circuitry

The candidate should be familiar with circuit implementation of linear power amplifiers (Ch. 9) and switched mode power amplifiers for high efficiency at RF frequencies. The candidate will understand the implications of the power amplifier on the design of transmitter circuitry and transmit architectures (Ch. 10).

Suggested Reference:

H. Darabi, 2015, *Radio-Frequency Integrated Circuits and Systems*, Cambridge; Chapters 1-10.

S. Voinigescu, 2013, *High-Frequency Integrated Circuits*, Cambridge; Chapters 1-10.

D. Pozar, *Microwave Engineering*, Wiley and Sons, Fourth Edition.

T. H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits,* Cambridge, Second Edition.

G. Gonzalez, *Microwave Transistor Amplifiers: Analysis and Design,* Prentice Hall, Second Edition.