ECE 662
Design of Communication Circuits
Fall 2019

Instructor: Dr. Kuhn 3114 Engineering Hall ece.k-state.edu/people/faculty/kuhn/

Office Hours: MWF 3:30 - 4:30 Others by appointment (or whenever my door is open)

Prerequisites: Electronics II (ECE526) and Electrical Engineering Lab II (ECE502), or permission.

Text Book: RF Circuit Design, Second Edition, by Christopher Bowick, et.al., Elsevier, 2008
Recommended - but not required (preview portions available on Google books)

References: Your Electronics course textbook/notes, and additional books in lab (do not remove !)

Course Description:

This course combines lectures and laboratory work to introduce you to the field of radio frequency (RF) circuit design and performance. ***An "open laboratory" format is used to provide optimum access to test equipment resources (See Lab Hours info on page 3).***

The primary objectives of the course are:

- to familiarize you with fundamental circuit design concepts used in wireless communications products,
- to introduce you to common laboratory test equipment and performance measurements used in product development, and
- to help you gain a solid foundation for specifying, designing, and using communications equipment at the system level.

The frequencies used in this course extend though the VHF range (about 150 MHz) but the circuits covered are fundamental to all modern wireless equipment, and are used through microwave frequencies when implemented "on-chip". Such circuits are found inside modern products ranging from cell phones to automotive safety radars.

Labs and Projects:

Work in this course centers around the design, construction, testing, troubleshooting, and documention of actual circuits. The labs/projects you will be required to complete are:

- Pjt 0: a simple amplifier design to help you review basic Electronics-2 concepts and learn construction, measurement, and documentation practices
- Pjt 1: a tuned-RF amplifier with impedance matching and bandpass filtering,
- Pjt 2: a voltage controlled oscillator,
- Pjt 3: a "downconverter" consisting of a mixer and IF filter, and
- Pjt 4: an IC-based IF-amplifier, demodulator, and audio amplifier.

These labs/projects take considerable time, but are in lieu of traditional homeworks. See below for weightings on assignments.

Project Kit: Each student will design/build their own copy of a radio transmitter and a radio receiver. Hence, ***each student*** will need to purchase a project kit (approx. $90). Kits will be sold during the first or second week of classes, and consist of two parts - an order from Digikey ($35+shipping) through the ECE webpage, and a set of additional parts stocked in the ECE Shop in Rathbone Hall for $45. Additional discrete components (e.g. resistors and capacitors) are available in the lab.

Midterm: At the completion of project 2 around the middle of the semester, you will have all the circuits needed to implement a radio transmitter operating in the FM broadcaset band. The midterm goal is to transmit voice from an on-board microphone to a commercial FM receiver using classic FM modulation. *You will also connect your circuits to an Arduino-based "data packet generator" to transmit digital radio FSK modulation similar to that used in Bluetooth products.* Demonstration and documentation of your transmitter will constitute the "***midterm exam***".

Final: At the completion of project 4, you will have all the circuits needed to implement an FM broadcast band receiver. *To help you understand digital radio, this will also be extended to demodulating digital packets using an Arduino-based digital back-end.* Demonstration and explanation of your circuits in an oral quiz setting will constitute the "***final exam***".

Teamwork: Design, construction, testing, debugging, and documentation of the projects takes considerable effort. Therefore, to help you out, some work may be carried out in teams of 2 students. This is intended to encourage you to bounce ideas off of each other, while at the same time potentially decreasing your overall workload. You may do projects 1 through 4 and their associated writeups in teams. ***<u>Project 0 and the midterm and final exams must be done individually</u>***. Additional information on teaming will be provided in class and/or with the project assignments.

Grading: Your grade in this course will be based on your understanding of circuits as demonstrated in documentation you will be required to turn in, on the successful operation and performance of your circuits, and on timely completion of the required work. *(See late policy below.)*

Weighting of the individual components of your grade will be computed as follows:

♦ Project 0	15% (5% construction, 10% writeup)
♦ Projects 1 through 4	15% each (see below)
♦ Demo/documentation of transmitter	20% (10% demo, 10% documentation)
♦ Demo/quiz on receiver	20% (Final: 10% demo and 10% for oral quiz)

Note that the weightings above total 115%. To return this to 100%, ***I will drop your lowest score <u>from projects 1 through 4</u>***. Projects 1 to 4 will be graded on the basis of Completeness, Correctness, and overall Quality (CCQ) with 5% on each of these categories, so that you can see what areas you may want to improve on.

The final grading curve is subject to the discretion of the instructor but will generally follow the classical assignment pattern: 90 - 100% = A, 80 - 90% = B, etc. so that you can keep track of your progress.

Late Work: To receive full credit, you must turn in your work by close-of-business (COB) on the due dates specified in class. Project writeups turned in late (without documentation of illness, or other significant circumstances outside your control) will be prorated as follows:

- < 2 business days — 0.9 times grade you would have received
- > 2 business days — 0.75 times grade you would have received

These penalties are significant and the policy will be strictly enforced, so do not let your grade suffer by falling behind in your work. Having said this, I recognize that you are taking several other classes and at times your workload may become very high. To help you address this problem, *I will drop your lowest score* ***on projects 1 through 4*** *as noted above. Of course, all the project construction work must still be completed in time to succeed in debugging/optimizing and demoing your circuits at the midterm and final !*

The "Midterm" and "Final" are treated as conventional exams and must be completed on time !

Lab: The Communications Circuits Laboratory (Engineering Hall 3097) is accessible using key-card access. ***DO NOT prop the door open, and always confirm that soldering irons are off when you leave (even if you didn't use them).***

Tools: Although soldering stations, solder, and drilling equipment is provided in the lab, you may benefit by having some of your own tools in this course and in your future careers. The minimum tools you are likely to need are listed below. Some of these are in the lab, but they are in varying conditions and you might want to have better ones of your own. Indeed, I recommend all engineers have a toolbox of their own, whether you bring it to class or not ! It is amazing how handy it will come in during your future career and life.

- Tool box
- Small diagonal cutters
- Small needle nose pliers
- Small wire stripper
- Small tweezers
- Folding (swiss army) knife (recommended)
- A set of test leads with small alligator clips (recommended)

Safety: While we will be working with low-voltage circuits, simple soldering materials, and small hand-tools, you should always be attentive to safety. In particular:

- use safety glasses when drilling, or around someone drilling,
- keep soldering irons in their holders when not in use, and
- turn them off when done ! (it also helps to keep the tips in better condition)

You may also want to read through the Material Safety Datasheets (MDS) in the lab to learn about the chemicals you may use. ***Above all, be careful in your work to avoid injuring yourself and others.***

Disabilities: If you have any condition, such as a physical or learning disability, which will make it difficult for you to carry out the work as outlined, or which will require academic accommodations, please notify me in the first two weeks of the course.

Academic Honesty as it Relates to this Course:

This is a challenging course configured as an open laboratory in which collaboration with other students is both desired and inevitable. It is structured to be very much like the workplace. *You are encouraged to seek help from your teammate, your fellow classmates, and/or your instructor as you learn the material and construct, test, and debug your circuits.*

However, ***in order to provide equitable grading, certain activities must be completed on your own. These include:***

- All work including construction and write-up for project 0.
- Assembly, modifications, and testing/demonstration of your midterm transmitter and your final receiver from the team-designed project pieces.
- The midterm service manual document and the final oral exam.

For projects 1 through 4 in which you will be allowed to work in a team, the design, construction, measurements and debugging, as well as the project writeup must be completed by you and your partner together, with a roughly equal amount of effort done by each. ***In particular, using designs from the web, from prior classes, or done by other teams, and/or copying any portion of such designs/measurements/writeups are strictly forbidden***. Additional information on load-division *within* a team will be given in the assignments and class. If you are unsure, then please ask in class so everyone knows the rules.

Finally, the obvious, as it relates to all courses:

Plagiarism and cheating are serious offenses and may be punished by failure on an exam, paper, lab, or project; failure in the course; and/or expulsion from the university. See *www.ksu.edu/honor*, and the above descriptions of what is and is not allowed in this course.

Workload:

This is a laboratory-based class, and as such, comes closer to the rules for out-of-class time required. Expect to spend 2 to 3 hours outside of class for every hour in-class. I.e. up to 18 hours on a 2-week project. (This is the guideline for all classes, but is more commonly needed in lab classes than in pure lecture ones).

Final Note:

I hope you enjoy learning how all the magical wireless devices you use on a daily basis are designed and built. Have fun !

ECE 662 Fall 2019 Schedule

(Tentative)

Week	*Material*	*Assignments*
1	Course Introduction, radio transmission, wireless link budgets, and received signal powers in dBm Signal generator, oscilloscope, and spectrum analyzer demos	
2	Soldering and connector assembly demos Electronics review: DC bias and AC circuits, transistor large/small signal models	Project 0 out
3	CE/CC/CB amplifier configurations, I/O impedances, coupling/bypass cap review Transistors at RF, resonance, and tuned RF amplifier design Resonant circuits, Q and bandwidth	Project 0 build due
4	Miller effects, stability, common-base and cascode circuits. Voltage vs. power gain Series/parallel equivalent circuits, impedance matching with L networks	Project 0 due Project 1 out
5	Component and board parasitics at RF. Introduction to transmission-lines Transmission lines and Smith Charts. Impedance measurements at RF	 Pjt 1 design due
6	Return loss, SWR, and introduction to S-parameters Network analyzers, calibrations, and demonstrations	Pjt 1 design back
7	Large signal response of amplifiers - compression and intermodulation Oscillator design, common base and common collector Colpitts configuration	 Pjt 1 due, Pjt 2 out
8	Frequency stability and phase noise, buffering, PLLs and VCOs, Analog and digital modulations (FM and FSK) and Bluetooth standards overview	 Pjt 2 design due
9	Transmitter designs, power amplifiers, FCC rules and regulations Antenna types and operational principles	Pjt 2 design back
10	Receiver design (tuned-RF, superhet, and direct-conversion architectures) Mixer design	Pjt 2 due, Midterm out
11	IC mixer circuit descriptions RF and IF Bandpass filters, filter technologies	Midterm due Pjt 3 out
12	IF amplifiers, IF limiting amps, and automatic gain control techniques FM Demodulator circuits	
13	FM IF subsystem integrated circuit descriptions Audio amplifiers	Pjt 3 due Pjt 4 out
14	Additional topics - Troubleshooting techniques	
15	Assemble receiver and test/debug. Bit slicing, bit/frame sync, bit-error-rate testing, and other digital comm topics	 Pjt 4 due
16	***Final Exam*** Demonstrate receiver and take oral quiz on its operation on or before Friday	

8/12/2019 WBK

Available Resistor/Capacitor Components

Leaded Components

Resistors and capacitors with leads are generally not suitable for circuits operating above about 30 or 100 MHz. There are a few in drawers in the lab, but you should not use them in your projects. Instead, we use surface mount components in this course.

Surface Mount Components

In addition to a few specific capacitor and inductor components in your kit, we have a decent stock of surface mount resistors and capacitors in the Comm Lab. SMD inductors are more limited - so you will get the joy of winding your own ;-)

For resistors, we have values from 10 Ohms to 2 MOhms in E12 series 10% increments only (i.e. 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82, 100, 120, etc.). The tolerance on these resistors is 5% and the power dissipation rating is 1/10 watt. There is also a reel of zero-Ohm resistors that can be handy for construction on our boards.

For capacitors, we have values from 0.5 pF to 0.1 uF in 10% increments. There are a few values above 0.1uF, like 1.0uF - but these should be used sparingly (only when absolutely needed like for the voltage regulators).

Low value capacitors are typically constructed using temperature-stable NPO dielectris. NPO caps range from 0.5pF to 820pF. Values of 1000 pF and above are in X7R or other higher permittivity dielectrics with worse (but not horrible) temperature stability. Tolerances are +/- 0.5pF for 10pF and below, +/- 5% for NPO types, and +/- 10% for X7R types. Voltage rating is at least 16V for the non-polarized caps we generally stock.

Size-wise, we have 0805 (0.08” x 0.05”) in the clear plastic boxes and 0603 parts in the assortment booklets.