EEAP 341
COMMUNICATIONS ELECTRONICS CIRCUITS

The first several lectures of EEAP 341 cover topics which appear in part of the EEAP 242 CIRCUITS II textbook ELECTRONIC DEVICES AND CIRCUIT THEORY by Boylestad and Nashelsky (henceforth abbreviated BN). The following reading list indicates what sections of BN and other course reference material would be appropriate for supplementary reading. Last years textbook SOLID STATE RADIO ENGINEERING by Krauss, Bostian and Raab will be referred to as KBR in the following list. Our new textbook MODERN COMMUNICATIONS CIRCUITS will be simply referred to as Smith.

NOTE: This list is subject to some revision as the class spends more or less time on a particular topic.

LECTURE TOPICS

1 **Review of dc biasing and bias stabilization for BJT's**
common base current gain: BN Section 3.1
leakage Current: BN Sections 3.5,3.6 (nice discussion)
common base configuration: BN sections 3.5, 4.3
common collector configuration: BN Sections 3.7, 4.10
common emitter configuration: BN Sections 3.6, 4.4, 4.5
transistor Q-point: BN Section 4.2
bias stabilization: BN Sections 4.6, 4.7, 4.8
design of bias networks: BN Section 4.12
computer program to calculate bias resistors: BN p.173-174

2 **h- and hybrid-pi small signal models**
variation of parameters with bias point
transistor data sheets: BN Section 3.9
h-parameter models: BN Sections 7.4, 7.5 (gives good insight)
hybrid-pi parameter models: Smith Section 2.2
variation of parameters: BN Section 7.6

3 **frequency dependence of small signal parameters**
input impedance and gain
small signal impedances and gains: BN Section 7.7
computer program to do ac analysis: BN p.244-245
approximations in real circuits: BN Section 7.8
general frequency considerations: BN Section 9.9
high frequency considerations: BN Section 9.11
small signal parameter conversions: BN Appendix A
high frequency models: KBR Section 4-2

4 **FET characteristics and circuits**
transfer characteristics: BN Section 5.2
JFET parameters: BN Section 5.3
MOSFET parameters: BN Section 5.4
FET biasing: BN Chapter 6 (excellent reading!)
small signal models: BN Section 8.3; Smith Section 2.3
design of a FET amplifier: BN Section 8.6

5 **Power amplifiers: Class A, B, AB and C amplifiers**
push-pull amplifiers: Smith Section 2.6
class A amplifiers: BN Sections 10.2, 10.3; Smith Section 11.2
classes of amplifiers: BN Section 10.4
class B and AB amplifiers: BN Sections 10.5, 10.6; Smith Section 11-3
Class C amplifiers: Smith Section 11.4

6 **Types of gain: transducer, operating and available**
gain in cascaded amplifiers: BN Section 9.2; Smith Section 2.4
decibels: BN Section 9.8
multistage frequency effects: BN Sections 9.12, 9.13
amplifier power gains: KBR Section 4-5
amplifier distortion: KBR p.194-196

7 **Comparison of amplifier topologies**
small signal equivalent circuits: BN Section 7.9; Smith Section 2.2

summary table: BN p.288-289
cascode amplifier: BN Section 9.6

8 **Superheterodyne radio concepts**
basic radio concepts: KBR Section 1-2; Smith Section 1.4
receiver performance specifications: KBR Section 9-1
RF ampifier: KBR Section 9-2
mixer: KBR Section 9-3
local oscillator: KBR Section 9-4
IF amplifier: KBR Section 9-5
diagram of an AM receiver: KBR Section 9-11

10 **Noise, signal/noise ratio**
noise: KBR Section 2-1; Smith Section 3.2
noise definitions: KBR Sections 2-4, 2-5; Smith Section 3.3
device noise: KBR Section 2-3, p.28-32; Smith p.72-76

11 **amplitude and frequency modulation and detection**
modulation principles: KBR Sections 1-3, 1-4
amplitude modulation: KBR Section 8-1
frequency modulation: KBR p.236-239
spectra of modulated signals: KBR Section 8-5
diode envelope detectors: KBR Sections 9-7, 9-8
FM demodulators: KBR Section 10-3

12 **Tuned circuits - resonance: series and parallel**
series and parallel resonance: KBR Sections 3-1, 3-2; Smith Sections 4.2, 4.3
effect of loading on circuit Q: KBR Sections 3-3, 3-4

13 **Tapped capacitor and inductor networks**
tapped capacitor networks: KBR p.49-53; Smith p.127-130
tapped inductor circuits: KBR p.53-62; Smith p.125-127
mutual inductance: KBR p.55-57

14 **Transformers, auto-transformers, single and double tuned i.f. transformers**
three-winding transformers: Smith Section 6.2
transformer coupled amplifiers: BN Section 9.4
real transformers with mutual inductance: KBR p.55-62
single tuned transformers: KBR Section 3-8; Smith Section 4.4
double tuned transformers: KBR Section 3-9; Smith p.123-125

15 **Matching networks**
impedance matching: Smith Section 4.5
series to parallel conversions: KBR Section 3-5
effect of loading on circuit Q: Smith Section 4.5

16 **Tuned rf amplifiers: frequency dependence of circuit parameters**
tuned amplifier technology: KBR Section 9-6
high frequency models: Smith Section 5.2
frequency response of amplifiers: Smith p.150-167

17 **Stability of rf amplifiers**

amplifier stability criteria: KBR Sections 4-3, 4-4
Miller's Theorem: Smith p.148-149

18 **Conditional and unconditional amplifier design**
design with unconditionally stable devices: KBR Section 4-6
design with potentially unstable devices: KBR Section 4-7
neutralization: Smith p.184-185

19 **RF amplifier design (continued)**
maximum gain design: KBR Section 4-8
alignability: KBR Section 4-9
cascode amplifier: Smith p.186-188
overall design procedure: KBR Section 4-10

20 **Mixers: spectral analysis, distortion, compression**
basic mixer theory: KBR Section 7-1
mixer terminology: KBR Section 7-2
balanced mixers: KBR Section 7-3
distortion and compression: Smith Section 3.5

21 **Mixer design: JFET, MOSFET mixers**
FET mixers: KBR Section 7-6
JFET mixer design: KBR Section 7-7
MOSFET mixer design: KBR Section 7-8

22 **Mixer design: BJT, diode ring mixers**
BJT mixers: KBR Section 7-5

23 **Basic oscillator principles**
feedback amplifier stability: BN Section 17.5; KBR Section 5-1
feedback oscillators: BN Section 17.6; KBR Section 5-3; Smith Section 7.2
negative resistance oscillators: KBR Section 5-2; Smith p.243-247

24 **Colpitts oscillator design**
Colpitts oscillator: BN Section 17.10; Smith p.240-243
Colpitts oscillator design: KBR Section 5-5; Smith p.240-243

25 **BJT, FET oscillators, crystal oscillators**
miscellaneous oscillator circuits: KBR Section 5-7
Hartley oscillators: BN Section 17.11; Smith p.240-241
crystal oscillators: BN Section 17.12; KBR Section 5-8; Smith Section 7.5

26 **Basic phase locked loops**
basic phase locked loops: BN Section 16.7; KBR Section 6-1; Smith Section 8.1
linear PLL analysis: KBR Section 6-2; Smith Section 8.2
PLL definitions: KBR Section 6-3
voltage controlled oscillators: BN Section 16.6; KBR Section 6-4; Smith Section 7.6, 8.4
phase detectors: KBR Section 6-5; Smith Section 8.3

27 **PLL fm demodulators**
fm demodulation: Smith p.319

PLL loop error analysis: Smith Sections 9.2, 9.3
PLL transient behavior: Smith Section 9.4

28 PLL frequency synthesizers
PLL synthesis: Smith Section 10.3
PLL frequency synthesizer design example: Smith Section 10.5

EEAP 341 COMMUNICATIONS ELECTRONICS CIRCUITS
Fall 1987

EEAP 341. Communications Electronics Circuits (4). Basic RF amplifier configurations, tuned circuits, coupled tuned circuits, impedance matching, amplifier stability, high-frequency amplifiers using transmission lines, oscillators, modulators and detection circuits, phase locked loops, receiver systems. Selected experiments and/or laboratory projects. Prerequisites: EEAP 242 and 243.

Textbook: Krauss, Bostian and Raab, Introduction to Solid State Radio Engineering, John Wiley, 1980.

References:

Christopher Bowick, RF CIRCUIT DESIGN
David Casasent, ELECTRONIC CIRCUITS
Ken Clarke and Donald Hesse, COMMUNICATIONS CIRCUITS ANALYSIS AND DESIGN
Mohammed Ghausi, ELECTRONIC DEVICES AND CIRCUITS: DISCRETE AND INTEGRATED
James Hardy, HIGH FREQUENCY CIRCUIT DESIGN
W. Hayward, INTRODUCTION TO RADIO FREQUENCY DESIGN
John Smith, MODERN COMMUNICATIONS CIRCUITS, McGraw Hill, 1987.

Instructor: F.L.Merat, Associate Professor of Electrical Engineering

Goals: To introduce students to the principles of rf communications circuits using discrete devices. Emphasis is placed upon extending previously developed device models to the rf domain, developing new techniques to analyze these models (two-port methods), and how to model non-linear circuits such as mixers and oscillators using linear models. This is integrated with a laboratory designed to emphasize practical circuit design and practices.

Prerequisites by topic:

- BJT and FET principles, biasing, amplifier analysis and modeling
- complex numbers and some simple matrix operations
- basic feedback theory
- two port networks (h-parameters)

Topics:

- Review of dc biasing and bias stabilization for BJT's, h- and hybrid-pi small signal models, frequency dependence of small signal parameters, input impedance and gain, FET characteristics and circuits (2 hours)
- power amplifiers: class A, B, AB and C amplifiers (6 hours)
- types of gain: transducer, operating, available, etc. (1 hour)
- superheterodyne radio concepts (1/2 hour)
- noise, noise bandwidth, signal/noise, noise equivalent temperature
- tuned circuits - resonance: series and parallel, L matching networks, tapped capacitor and inductor networks, transformers, tuned transformers (6 hours)
- tuned amplifiers: frequency dependence of circuit parameters, stability of r.f. amplifiers, conditional and unconditional amplifier design (6 hours)
- mixers: spectral analysis, distortion and mixer design: JFET and MOSFET, BJT and diode ring (3 hours)
- oscillation criteria, Colpitts oscillator, BJT, FET oscillators, crystal oscillators (5 hours)

- basic phase locked loop components, systems analysis of phase locked loops, design of a PLL frequency synthesizer and FM demodulator (5 hours)

Laboratory Projects:

- Learn to use high frequency scopes and waveform generators
- Write computer program to design BJT amps, test in lab.
- Complementary symmetry power amplifier (2 weeks)
- Diode detector
- Frequency response of RLC circuits, i.f. transformers (illustrate impedance matching with lamp and coil).
- Tuned i. f. amplifier (2 weeks).
- Optional oscillator lab (2 weeks).
- Optional phase-locked loop lab (this is a measurement only lab)

Estimated ABET Catagory Contents:

Engineering Design: 2 credits or 50%
Engineering Science: 2 credits or 50%

*** COURSE GRADING POLICY ***

Three (3) equally weighted exams	45%
Laboratories	30%
Homework	20%
Radio project report	5%

NOTES:

1. NO STUDENT CAN GET AN "A" WITHOUT A DEMONSTRABLE WORKING RADIO.
2. THERE WILL BE NO FINAL AS SUCH. THE LAST EXAM (TO BE GIVEN IN FINALS WEEK) WILL BE A NORMAL ONE-HOUR EXAM COVERING THE LAST THIRD OF THE COURSE.
3. EXAMS 1 AND 2 WILL BE GIVEN IN THE EVENING AT TIMES AND DATES TO BE ANNOUNCED.

Your grade will be based upon a strict interpretation of the above formula, i.e. points=0.45×(average exam score)+0.30×(average lab score) + 0.20×(average homework score) out of a possible 100 points. A working radio can raise a students grade one letter grade under the following conditions:

(1) the student has a satisfactory overall performance, i.e. no missing exams, etc.
(2) all labs handed in
(3) a working radio
(4) two or more exams at the higher grade level.

For example, a student with a "B" average but two "A" level exams will receive a course grade of "A" provided he/she meets the above criteria. For your reference, last year's grade cutoff's were:

A	points≥84
B	points≥73
C	points≥64
D	points≥50
F	points<50

IMPORTANT ANNOUNCEMENT

The T. A.'S WILL BE AVAILABLE ONLY DURING SCHEDULED LAB HOURS. THERE IS A MINOR PROBLEM WITH HAVING A T.A. PRESENT DURING SOME OF THE LAB PERIODS BUT THIS WILL HOPEFULLY BE CORRECTED SHORTLY.

YOUR LAB'S WRITE-UPS FOR LABS 1-3 ARE DUE THE END OF SEPTEMBER. WE ARE ATTEMPTING TO DO AS LABS AS POSSIBLE NEAR THE BEGINNING OF THE SEMESTER.

YOU WILL RECEIVE A BAG OF COMPONENTS YOUR FIRST LAB SESSION SO IT IS IMPERATIVE YOU ATTEND. THIS BAG CONTAINS ASSORTED CAPACITORS, TRANSISTORS AND VARIOUS MECHANICAL COMPONENTS YOU WILL NEED IN LATER LABS. ADDITIONAL COMPONENTS SUCH AS TUNED TRANSFORMERS, ANTENNAS AND VARIABLE CAPACITORS WILL BE ISSUED DURING LATER LAB SESSIONS.

USE THE PROTOBOARD IN YOUR TOOL BOX TO BUILD YOUR FIRST LABS. THESE WILL BE LATER (OPTIONALLY) BE TRANSFERRED TO PRINTED CIRCUIT BOARDS.

28	design of a PLL frequency synthesizer
29	design of a PLL FM demodulator
30	review (or a breather)

EXAMINATION TOPICS

Exam #1	Circuits: power amplifiers, amplifier topologies, small signal models, two port networks, bias stability, impedance and gain
Exam #2	radio systems, modulation, detectors, resonant circuits, impedance matching, transformers
Exam #3	mixers, oscillators, PLL's

Instructor: Prof. F. Merat
Office: Glennan 515
Office hours by appointment

Comments about EEAP 341:

1. No matter what textbook is used – use the homeworks from KBR as example problems.

2. The PC board for the i.f. amplifier got screwed up again. DO NOT use any california firms for pc boards again!!! Make sure that the correct artwork is sent out and don't send out the original artwork. This year's had the transformer leads grounded and the transformer connections reversed, i.e. the connections going to the transformer from the transistor collector are reversed. The output of the transformer should also be grounded.

3. The review sessions are important. Start them immediately and only do one a week. From experience the one on Tuesday night is the best.

4. Assign two homework problems per week – irregardless of exams. Then give the students the option of dropping four homeworks. This will allow students to skip homework on exam week or when labs, etc. are due but still give them 15 × 2 = 30 problems less 4 × 2 = 8 or 22 graded homwork problems.

5. Give out an assigned homework, lab, lecture and exam schedule and FOLLOW it from day one.

6. All exams will be three question and will be closed book.

7. Four exams (with the option of dropping one of the first three) seems like a good possibility.

8. There are some problems with lab #5. Check the schematic carefully. I also think some of the components on the parts list are incorrectly labeled. We did not use the correct PC board – don't mess this up again. Consider also including a simplified schematic with NO decoupling components. Students seemed to be confused by all the components. Check the Page Setup for lab #5. Its margins, etc. don't seem to be correct.

9. Have someone make up a little test fixture for the single–tuned and double–tuned i.f. transformers for lab

#4.

10. The signal generators and scope probes MUST be checked out before lab #4 is done. The soldering irons MUST be checked out before lab #3 is done.

11. Have the Stores stock i.f. transformers and other special components for EEAP 341.

12. Order a lot of 9 volt batteries for EEAP 341.

13. Lab #6 has the wrong PC board. It needs to be modified to have the new PC board.

CLASS NOTES AND/OR REFERENCE MATERIAL:
Clarke and Hess

Have a two question homework due every week, say 15 of them. That's only 30 problems. This will increase student participation in homeworks. Allow student to drop 8 of them. Except that a homework problem will be on exams.

Have a fourth exam. The first exam should be about September 15th and cover BJT's, FET's, biasing, etc. The lowest exam score would be dropped.

DO NOT get the artwork for the if amplifier PC board messed up!!!

There should be one recitation/lab lecture once per week beginning immediately in the semester.

Use KBR.

Don't be afraid to skip a lot of material. Students CAN read it. Particularly in the beginning.