SIMULATION OPTIMIZATION SYSTEMS
Research Laboratory

**TEACHING SIMULATION AND
OPTIMIZATION-ORIENTED CAD
TO UNDERGRADUATES IN 1995**

SOS-95-07-V

May 1995

J.W. Bandler

McMASTER UNIVERSITY
Hamilton, Canada L8S 4L7
Department of Electrical and Computer Engineering

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Simulation Optimization Systems Research Laboratory
and Department of Electrical and Computer Engineering
McMaster University, Hamilton, Canada L8S 4L7

Course: Computer Engineering 3KB3
Simulation and Optimization I

Department of Electrical and Computer Engineering, McMaster University

Originator: John W. Bandler

Instructor: John W. Bandler

Required Course (Year 3)

Prerequisites

   Circuits and Systems (Year 2)
   Computational Methods (Year 2)

Course: Computer Engineering 4KC3
Simulation and Optimization II

Department of Electrical and Computer Engineering,
McMaster University

Originator: John W. Bandler

Instructor: Radek M. Biernacki

Elective Course (Year 4)

Prerequisites

Simulation and Optimization I (Year 3)

Course Objectives 3KB3

to introduce fundamentals of

modern engineering-oriented simulation and
optimization practices

optimization-driven CAE technology

computational environments for design:
Fortran, C, UNIX, X-Windows

CAD systems

CAD simulation/optimization algorithms

linear and nonlinear equations
for analog simulation

adjoint circuits

design with tolerances

Course Objectives 4KC3

to introduce advanced concepts in

 simulation and optimization

 applications in modern CAD practice

 emphasis on high-frequency and microwave analog circuits

 simulation of linear and nonlinear circuits

 statistical fluctuations in ICs

 worst-case design

 statistical modeling

 yield optimization

Textbooks and Reference Material 3KB3

J.W. Bandler, *Optimization, Volume 1*,
Dept. Electrical and Computer Engineering,
McMaster University, Hamilton, ON, Canada,
January 1995.

J.W. Bandler, *Optimization, Volume 2*,
Dept. Electrical and Computer Engineering,
McMaster University, Hamilton, ON, Canada,
January 1995.

OSA90/hope™ Version 3.0 User's Manual,
Optimization Systems Associates Inc.,
Dundas, ON, Canada, 1994, 650 pp.

Press, Flannery, Teukolsky and Vetterling,
Numerical Recipes in C, Cambridge, MA, 1989. Also,
Numerical Recipes C Diskette, Cambridge, MA, 1987.

Notes, solutions, reprints and reports.

Textbooks and Reference Material 4KC3

as for 3KB3 plus

OSA90/hope™ Applications Illustrated Version 2.5,
Optimization Systems Associates Inc.,
Dundas, ON, Canada, 1994, 180 pp.

Registration, Assignments and Labs 3KB3

four classroom assignments or tests carried out during the tutorial period

tests marked later and count towards the final grade

programming assignments: students are asked to do assignments in C

students work in groups of two at each of 15 Sun SPARC workstations

prelab tasks have to be performed

approximately 100 undergraduates register every year

Registration, Assignments and Labs 4KC3

four classroom assignments or tests carried out during the tutorial period

tests marked later and count towards the final grade

homework assignments: one optional project is suggested late in the term

students work in groups of one or two at each of 15 Sun SPARC workstations

prelab tasks have to be performed

approximately 20 undergraduates register every year

Computer Engineering 3KB3
Simulation and Optimization I:
Description

optimization-oriented
computer-aided engineering

CAD systems

optimization fundamentals and algorithms

non-linear equations

approximation practice

adjoint network gradients

sensitivities

tolerances

two lectures, one lab or tutorial (three hours)

Optimization-driven CAE (3KB3)

objectives and objective functions

constraints and constraint functions

formulations of design problems

designable variables

applications in modeling, simulation and design of electrical circuits and systems

computational environments: Fortran, C, UNIX, X Windows

CAD Systems (3KB3)

input files and netlists

circuit description

expression processing

linear and nonlinear models

simulators

optimizers

user interface menus

layout, schematic capture

output file

graphical outputs

CAD Optimization: Fundamentals (3KB3)

linear and nonlinear programming

approximating and specified functions

norms, constraints, bounds, transformations

penalty methods, barrier methods

Kuhn-Tucker conditions, feasible directions

upper and lower design specifications

weighting factors for design

minimax objectives and minimax optimality

steepest descent-type and Newton-type approaches

least pth optimization

Algorithms (3KB3)

one-dimensional searches, Golden section

direct search, pattern search

simplex method

conjugate directions

gradient methods

Newton-based methods, damping

quasi-Newton methods

conjugate gradient

step-size, termination and convergence

Equations for Simulation (3KB3)

equations for linear and nonlinear simulations

large scale systems

circuit applications

Newton approach revisited

companion network method

Adjoint Circuits (3KB3)

difference form of Tellegen's Theorem

applications to circuit simulation and sensitivity analysis in the frequency domain of lumped and distributed circuits

adjoint circuits

elements and excitations

derivatives

tolerance analysis

gradient verification

nodal and cascaded systems

Computer Engineering 4KC3
Simulation and Optimization II:
Description

analog IC and system simulation

advanced optimization techniques

design centering, tolerancing and tuning

use of professional CAD software

VLSI and MMIC applications

two lectures, one lab or tutorial (three hours)

Analog IC and System Simulation (4KC3)

linear and nonlinear analog ICs

VLSI and MMIC

modeling

simulation

performance-driven design

yield-driven design

cost-driven design

Abstract Linear/Nonlinear Simulation (4KC3)

vectors and matrices

selection

assembly

derivative operations on inverses

nonlinear equations

simulation

applications

active and passive element models

Sensitivity Analysis of Nonlinear DC Circuits (4KC3)

abstract formulation

adjoint companion circuit

electrical circuit interpretations

Advanced Linear Simulation (4KC3)

modified nodal equations

adjoint circuit

scattering parameters

Advanced Nonlinear Simulation (4KC3)

steady state in linear and nonlinear circuits

phasor vectors, spectra, truncation, DFT

harmonic balance equations

Sparse Matrix Techniques (4KC3)

solution of large systems

operation count

storage

data structures

pivoting for sparsity

fill-ins

sparsity of circuit matrices

Advanced Optimization Techniques (4KC3)

directional derivative, reduced gradient

exact and approximate penalty functions

norms and objectives: ℓ_1, ℓ_2, ℓ_p, Huber, minimax

one-sided and two-sided objectives

device modeling

parameter extraction

analog fault diagnosis

Design Centering, Tolerancing and Tuning (4KC3)

optimization subject to tolerances and uncertainties

error functions in circuit design

the acceptability region defining circuit optimization problems

cost functions

worst-case design, vertex selection

centering

tolerance assignment

tuning

statistical modeling/yield optimization

Laboratories 3KB3

Lab 1:   *Introduction to the Sun SPARCstations*

to familiarize students with the UNIX environment on
Sun SPARCstations

Lab 2:   *LC Transformer Simulation Using C*

C programming project for a ladder network; this is a
prelab to Lab 5

program to be completed, debugged and executable on
a SPARCstation by a later date; a written report is due

Lab 3:   *Introduction to OSA90/hope™*

to become acquainted with the concept of, and skilled in
employing the file editor

to learn how to use input or circuit files

there is also a guided tour of the OSA90/hope™ CAE
system

Laboratories 3KB3

Lab 4:   *Simulation of an LC Transformer*

use OSA90/hope™ to simulate a ladder network

use concepts of circuit descriptions, expressions, graphics manipulation and report generation

Lab 5:   *Simulation, Optimization, Datapipe, C*

the C program developed for Lab 2 is to be connected to OSA90/hope™

implement the C ladder network routine via the UNIX interprocess Datapipe

compare the results with the built-in circuit file capabilities in solving the same problem

engineering design-oriented simulation and optimization are performed using both concepts

Laboratories 3KB3

Lab 6:   *Advanced Applications*

Part 1: students carry out a laboratory in nonlinear
function approximation

Part 2: a guided tour of advanced applications and
problem solving using OSA90/hope™, including minimax
and ℓ_1 optimization, optimal design and device
parameter extraction

Laboratories 4KC3

Lab 1:   *Introduction to OSA90/hope™*

to refresh hands-on experience with OSA90/hope™, UNIX and X Windows gained during 3KB3

guide through some new features available in the latest versions of the software

Lab 2:   *Nonlinear Memoryless Circuits: DC and Time-Domain Simulation*

a full-wave diode rectifier is investigated

analytical linearization is compared with computer simulation

built-in simulators of OSA90/hope™ are used to carry out various DC analyses as well as time-domain analysis

DFT of the rectified voltage waveform is used to illustrate the frequency-domain representation of periodic signals

Laboratories 4KC3

Lab 3:   *Performance-Driven Design of Nonlinear Circuit*

a simple single-stage amplifier is considered

nonlinear DC/linearized small-signal AC simulation

performance-driven design with built-in optimizers and simulators of OSA90/hope™

design includes achieving desired biasing conditions and the frequency response

students formulate and optimize user-defined responses derived from the basic built-in responses of OSA90/hope™

large-signal simulation is used to reveal harmonic distortion of the amplifier

Laboratories 4KC3

Lab 4:   *Device Modeling from Experimental Data*

device models of various complexity and applicability
are investigated

the model parameters are extracted from real
measurement data using the built-in optimizers and
simulators of OSA90/hope™

the concepts of different models

> small-signal
> large-signal
> linear
> bias-dependent
> nonlinear

and the state-of-the-art technique of applying
optimization to device modeling are included

Laboratories 4KC3

Lab 5:   *Statistical Design Centering*

statistical Monte Carlo analysis is applied to

(1) a simple voltage divider
(2) a single-stage amplifier

to investigate the influence of statistical variations of
circuit parameters on the circuit responses

yield-driven design of the amplifier is carried out using
OSA90/hope™