As a lab course that utilizes much specialized equipment that is only provided in the classroom itself, options are very limited. One lab experiment, Interactive Graphical Simulation, can be completed remotely and will be used to replace one of the 5 required lab experiments. Several of the last few scheduled lab experiments can be fairly accurately simulated using MATLAB. Data and plots can be acquired after following the lab procedures and implementing the systems in MATLAB Simulink or with other provided m-files. There are many online references on the course web site and that material should be incorporated into the lab reports, especially to enhance sections of the procedures that can’t be done experimentally. All reports will continue to be submitted electronically.

Since lectures for the semester have been completed, with the exception of the final review lecture, little change is necessary. The review slides for the final exam are posted on the course web page, https://www.rpi.edu/dept/ecse/rta/. Students will be able to review them on their own time and any questions for the instructor or TA will be handled by email. Previous semester final exams are already available on LMS and the course web page.

If necessary, the final will be administered remotely through LMS under the usual timed limitations and individual efforts (no student collaborations) under the Rensselaer Academic Integrity umbrella. Questions will accommodate any restriction place on students as far as completing all the normally required labs.

Assuming that accommodations can be made for best efforts on lab results from simulations instead of actual physical system measurements, reports will be graded accordingly. Student teams may collaborate within the teams remotely to determine who will be responsible for which parts of the lab experiments. Then collate all the results into a single report. Some teams may actually get together to work on the experiments. This will be encouraged but not necessarily required. The TA and instructor will also be readily available to answer questions or provide suggestions by email or video conferencing at the request of students.

Of the remaining labs chosen by the students, the Voice Processing experiments would be the most difficult to perform remotely. Students will be required to substitute the Interactive Graphical Simulation lab experiment since that is one that can be done individually and off-campus easily.

Final grades for the course will follow the original syllabus weightings on lab report grades, 2 exam grades, and participation based mostly on performance of the first 3 lab experiments.

Any issue arising will be dealt with on a case-by-case basis through the instructor and/or TA by email.
ECSE-4760 REAL-TIME APPLICATIONS IN CONTROL & COMMUNICATIONS

Course Catalog Description: Experiments and lectures demonstrate the design and use of microcomputers as both decision tools and on-line real-time system components in control and communications. Topics include the basic operations of microcomputers, data I/O, analog & digital process control, voice processing, digital filter design, digital communication, and optimal LQR control. Prerequisites: ECSE-2410 and one of ECSE-4520 or ECSE-4440. ECSE-4530 is helpful.

Spring term annually. 3 credit hours, 5 contact hours

Pre-Requisite Courses: ECSE-4440 Control Systems Engineering or ECSE-4520 Communication Systems

Co-Requisite Courses: None

Prerequisites by Topic: 1. Basic knowledge of linear systems 2. Basic knowledge of discrete-time systems 3. Basic knowledge of analog and digital filters 4. Basic knowledge of digital modulation and error coding 5. Basic knowledge of LabVIEW and the “C” programming language and microcomputer structure is helpful but not essential

Textbook: None (all the essential material is available from the course web site)

R.C. Dorf, “Modern Control Systems”, Addison-Wesley, 1980
Several other textbooks about digital systems kept on reserve in the library for the course (the complete list is included below), and a comprehensive lab manual.

Online: www.ecse.rpi.edu/Courses/CStudio and http://www.rpi.edu/dept/ecse/rta

Course Coordinator: Russell Kraft, Electrical, Computer and Systems Engineering
CII-6219, krafr2@rpi.edu, 518-276-2765

Overall Educational Objective: To give students hands-on laboratory experience with analog and digital control and communication systems. The laboratory environment provides students with an opportunity to use a variety of instruments and equipment as well as industrial quality instrumentation software.

Course Learning Outcomes: (5 of 8, by choices of labs) Students who finish the course will be able to: 1. Design a PID controller for specific plant types 2. Design a state space controller for specific plant types 3. Create a digital controller by Tustin approximation from an analog controller 4. Solve continuous and discrete Riccati equation to design an LQR 5. Design a simple logic state machine (8-12 states) 6. Evaluate performance trade-offs in a delta modulator voice transmission system 7. Design impulse and step invariant digital filters from analog filters 8. Evaluate parity and hamming codes for bit rate, efficiency, and bit error rate for given SNR.

How Course Learning Outcomes are Assessed: Part of each grade will be determined by the team effort on experiments and the graded report and part by individual effort on the 2 exams and lab performance.

<table>
<thead>
<tr>
<th></th>
<th>Exp. procedures &amp; reports (6 total)</th>
<th>Exams (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp.</td>
<td>Reports (6)</td>
<td>50%</td>
</tr>
<tr>
<td>Performance/Preparation</td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Exams:</td>
<td>Test 1</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>Test 2</td>
<td>25%</td>
</tr>
</tbody>
</table>
Relation to EE/CSE/EPE Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Level</th>
<th>Demonstrate Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics, science and engineering</td>
<td></td>
<td>N, M, H e.g. Exams, projects, HW</td>
</tr>
<tr>
<td>Basic disciplines in Electrical Engineering</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Depth in Electrical Engineering</td>
<td>M</td>
<td>Lab experiments</td>
</tr>
<tr>
<td>Depth in Computer and Systems Eng.</td>
<td>H</td>
<td>Lectures &amp; Lab exp.</td>
</tr>
<tr>
<td>Basic disciplines in Electric Power Eng.</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Conduct experiments and interpret data</td>
<td>H</td>
<td>Lab experiments</td>
</tr>
<tr>
<td>Identify, formulate and solve problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design a system, component or process</td>
<td>M</td>
<td>Lab experiments</td>
</tr>
<tr>
<td>Communicate in written and oral form</td>
<td>M</td>
<td>Lectures &amp; Lab exp.</td>
</tr>
<tr>
<td>Function as part of a multi-disciplinary team</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Preparation for life-long learning</td>
<td>M</td>
<td>Lab experiments</td>
</tr>
<tr>
<td>Ethical issues; safety, health, public welfare</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Humanities and social sciences</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Laboratory equipment and software tools</td>
<td>H</td>
<td>Lab experiments</td>
</tr>
<tr>
<td>Variety of instruction formats</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

Topics Covered:
(number of hours or classes for each)

1. Mathematical models: z-transforms, difference equations and software implementations
2. Microcomputer architecture (CISC, RISC, and DSP)
3. Real-time and multi-processor systems, Co-processors, pipeline processors, array processors, and image processors
4. Peripheral interfacing and data conversion (including over-sampling and sub-ranging converters)
5. Optimal control with a linear quadratic regulator (continuous and discrete)
6. Analog and digital control
7. Digital communication and voice processing
8. Digital filters

Computer Usage:

In all laboratory procedures, experiments are performed with the use of computers, either PCs (with ADACs and DSP boards) or engineering workstations and use either commercially available software packages (e.g., MATLAB, LabVIEW, LogicWorks, Data Explorer) or programs developed at Rensselaer.

Laboratory Experiences:


Design Experiences:

The directed design experiences vary with the selected experiments, but all involve: 1. Determining the problem to be solved 2. Mathematically modeling the system and solving the equations to determine appropriate values to be used in the experiment 3. Verifying the correctness of the model and solutions with the acquired data and recorded performance.

Independent Learning Experiences:

Although students work in teams, they are evaluated individually in their lab preparation & performance and on the 2 course exams. In the performance of the various experiments, students will divide up tasks between themselves such as: 1. Developing the equations describing a system and its control and researching reference material 2. Setting up computer solutions to a series of equations 3. Setting up the lab equipment 4. Recording data for a series of experiments

Class/Lab Schedule:

(See following pages)

Contribution to the Professional Component:

(a) College-level mathematics and basic sciences: 0 credit hours
(b) Engineering Topics (Science and/or Design): 3 credit hours
(c) General Education: 0 credit hours

Prepared by: Russell P. Kraft
Date: 2/6/2023
For all experiments except the Introductory Lab, students work in teams of only 2. Individual reports are required for the Introductory Lab Experiment while the other 5 require only one team report. Reports need Grade Form cover sheet and TA signed and dated data sheets. Reports are due 4 days after the completion of the experiment (on Mon. when they begin the next experiment). Late penalty is 2% per day late.

**TA(s):**

Weiqin Chen  
chenw18@rpi.edu

**Experiment Procedures:** There is no course textbook, just the lab experimental procedure files (found on the LMS pages and [https://www.rpi.edu/dept/ecse/rtacoursematerial.html](https://www.rpi.edu/dept/ecse/rtacoursematerial.html)). The web site also contains copies of previous quizzes with and without solutions and a few relevant articles. All 6 lab experiments must be successfully completed to pass the course. Most experiments need to be performed in the lab due to equipment requirements and all data/observations must be signed and dated by a TA as proof of participation.

**Academic Integrity:** Academic dishonesty is a very serious matter, and we suggest that you read the remainder of this statement carefully:

Student-teacher relationships are built upon trust. For example, students must trust that teachers have made appropriate decisions about the structure and content of the courses they teach, and teachers must trust that the assignments, which students turn in, are their own. Acts that violate this trust undermine the educational process.

The Rensselaer Handbook defines various forms of Academic Dishonesty and procedures for responding to them. All forms are violations of the trust between students and teachers. Students should familiarize themselves with this portion of the Rensselaer Handbook and should note that the penalties for plagiarism and other forms of cheating can be quite harsh.

Any portion of work handed in that is not your own, should cite the author. Just as you would not write a history paper by copying text from the encyclopedia, you should not take credit for another person’s engineering work. Reference should also be made to any personal communications you have had with anyone outside your group that contributed substantially to the successful completion of assignments. (Read the IEEE Code of Ethics, especially item #7: [http://www.ieee.org/web/membership/ethics/code_ethics.html](http://www.ieee.org/web/membership/ethics/code_ethics.html). The ASME has a similar code: [http://files.asme.org/ASMEORG/Governance/3675.pdf](http://files.asme.org/ASMEORG/Governance/3675.pdf).)

Collaboration on assignments is encouraged, in fact essential, between lab partners. However, having one partner always work on hardware aspects and the other on the software or data analysis or report writing will be detrimental to all partners. All partners should understand and participate in all aspects of the lab exercises in order to learn the necessary topics addressed in lab write-ups and covered on the exams. While you may discuss your classwork with anyone, collaboration on assignments is not allowed between lab groups, either within or between lab sections. Turning in similar out-of-class assignments, which suggest that copying (in part or in total) has taken place, will be considered as academic dishonesty.

Cheating on an exam will be considered as academic dishonesty and will result in a failing grade for the course.

At all times, we reserve the right to take formal action against anyone engaging in academic dishonesty. This action may range from failing an assignment to failing the course, or to being reported to the Dean of Students. If you have any questions about these rules or how they apply to any specific assignment or exam, discuss it with one of the instructors or course administrators.
# Lecture Schedule – JONSSON 6309

<table>
<thead>
<tr>
<th>DATE</th>
<th>TOPIC</th>
<th>SPEAKER</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 9</td>
<td>Introduction</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>January 12</td>
<td>Mathematical Models: Z-Transforms and</td>
<td>R. Kraft</td>
</tr>
<tr>
<td></td>
<td>Difference Equations</td>
<td></td>
</tr>
<tr>
<td>January 16</td>
<td><strong>Martin Luther King, Jr. Day</strong></td>
<td></td>
</tr>
<tr>
<td>January 19</td>
<td>CISC, RISC &amp; DSP Microprocessor</td>
<td>R. Kraft</td>
</tr>
<tr>
<td></td>
<td>Architecture</td>
<td></td>
</tr>
<tr>
<td>January 23</td>
<td>Special Hardware and Coprocessors</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>January 26</td>
<td>Peripheral Interfacing and</td>
<td>R. Kraft</td>
</tr>
<tr>
<td></td>
<td>Data Conversion</td>
<td></td>
</tr>
<tr>
<td>January 30</td>
<td>Control I (general, Hybrid, Optimal)</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>February 2</td>
<td>Control II (general &amp; DC Motor)</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>February 6</td>
<td>Digital Communications I (Graphics)</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>February 9</td>
<td><strong>(No Lecture, Catch-up Lab time)</strong></td>
<td></td>
</tr>
<tr>
<td>February 13</td>
<td>Digital Filters</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>February 16</td>
<td>Digital Communications II (Voice)</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>February 20</td>
<td><strong>PRESIDENTS’ DAY</strong></td>
<td></td>
</tr>
<tr>
<td>February 21</td>
<td><strong>EXAM No. 1</strong></td>
<td>R. Kraft</td>
</tr>
<tr>
<td>February 23</td>
<td>Digital Communications III (Binary Comm)</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>February 23</td>
<td>Miscellaneous Topics (Final lecture)</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>March 6 &amp; 9</td>
<td><strong>END OF LECTURES</strong></td>
<td></td>
</tr>
<tr>
<td>March 6 &amp; 9</td>
<td><strong>SPRING BREAK</strong></td>
<td></td>
</tr>
<tr>
<td>April 24</td>
<td>Exam 2 Review</td>
<td>R. Kraft</td>
</tr>
<tr>
<td>May ? (Finals Week)</td>
<td><strong>EXAM No. 2</strong></td>
<td></td>
</tr>
</tbody>
</table>
Lab Schedule - JONSSON 6309

Important Dates:
1/12 (Thu.) Go to lab to begin Intro exp. (Or the following Monday, watch web broadcast of procedure)
1/26 (Thu.) Hand in lab preference sheet by today (with chosen lab partner if desired)
1/27 (Fri.) Semester lab schedule will be posted on LMS & lab door (JEC-6309). Check to see for which exp. to prepare on 1/31
2/13 (Mon.) Exam #1
5/?? Exam #2 (Finals Week)

WEEKS OF SEMESTER

1/12, 1/18 1/19 1/23 2/26 Intro. Exp.
Meet during scheduled session (Thu.) of first week for lab, read web handouts, etc.
and begin Introductory Lab. Experiment.
Preference sheets due 3rd week.
Schedules for semester posted Thu. or Fri.

1/30 - 2/9 Exp. #1
2/13 - 2/23 Exp. #2
2/27 - 3/16 Exp. #3
3/20 - 3/30 Exp. #4
4/3 - 4/13* Exp. #5

Final deadline for all reports is the last day of classes of the semester unless you have a valid excuse (make-up lab time lost to illness). In that case the deadline is the Friday before Final Exams begin.

Select five experiments from the list below:

- Digital Logic (Experiments in Digital Logic Design)
- Voice Processing (Digital Voice Processing / Delta Modulation)
- Binary Communications (Binary Communications)
- Digital Filtering (Digital Filter Design)
- Graphics Simulations (Graphics Simulation Experiments)
- Hybrid Control (Hybrid Simulation of a Controlled System)
- DC Motor (Analog and Digital Control of a DC Motor)
- Optimal Control (Experiments in Optimal Control)
In addition to the messages posted in the RTA directory on the web (http://www.rpi.edu/dept/ecse/rta/) and LMS (http://rpilms.rpi.edu), you may receive from and send to the instructor and TAs messages using email.

Email addresses, Offices, & Phone numbers:

Instructor: Russell Kraft kraftr2@rpi.edu JEC-6028 x2765
TAs: Weiqin Chen chenw18@rpi.edu JEC-6308 x????

NOTE: All TAs are subject to change. Changes will be announced in lecture.

Section 3.4 of the COURSE INTRODUCTION is posted as a reminder of the main laboratory procedure and grading policies in effect.
References in Library
(Many key references are available under Course Material handouts on the web.)

Cadzow & Martens  Discrete-Time and Computer Control Systems
Carlson, A. B.  Communication Systems
Cosgriff, R. L.  Nonlinear Control Systems
DeRusso, Roy, & Close  State Variables for Engineers (Chow)
Dorf, R. C.  Modern Control Systems
Frederick & Carlson  Linear Systems in Communication and Control
Gold & Rader  Digital Processing of Signals
Kohavi, Zvi  Switching and Finite Automata Theory
Kirk, D. E.  Optimal Control Theory
Ledley, R. S.  Digital Computer and Control Engineering
Melsa & Schultz  Linear Control Systems
Mowle, F. J.  A Systematic Approach to Digital Logic Design
Oppenheim & Schafer  Digital Signal Processing
Osborne, A.  An Introduction to Microcomputers
Peatman, J. B.  Microprocessor Based Design
Peterson, W. W.  Error Correcting Codes
Ragazzini & Franklin  Sampled-Data Control Systems
Shinners, S. M.  Modern Control System Theory and Application
Stout, D. F.  Microprocessor Applications Handbook
Williams & Ryan  Progress in Direct Digital Control

The course LMS item “General Course Information” and “RTA Laboratory Information” will be used to post the latest updates, corrections, and information about the lab, especially experiments using the workstations.
List and Brief Descriptions of Experiments

**Introductory Lab Experiment** - Introduces students to the microcomputer and peripherals by simulating a digital voltmeter, signal sampler, simple low order digital filter/signal processor, and a signal generator. The student also learns how the peripherals and the I/O devices operate and writes some simple LabVIEW visual programs to use them.

**Experiments in Digital Logic Design** - Simple logic circuits using AND, NAND, OR, NOR, INVERTERS, and flip-flops can be simulated by graphically drawing them with a special microcomputer simulator program. Through the simulations the students learn about combinational logic, Karnaugh maps, flip-flops, counters, and synchronous circuit synthesis.

**Digital Voice Processing/Delta Modulation** - The effects of quantization, sample frequency, and low pass filter reconstruction are observed on voice signals. The trade-offs in the design of 2 and 4 level delta modulators are observed and analyzed.

**Binary Communications** - Three phases of binary communications are studied: digital modulation techniques, error-control coding, and transmission of coded signals. The modulation and coding techniques are tested for their robustness by adding varying amounts of noise to the transmission channel to determine their useful thresholds.

**Digital Filter Design** - The microcomputer or a DSP board is used to implement a 4th order digital filter whose characteristics (low, high, band, Butterworth, Chebyshev, or elliptic) depend on the values assigned to its 10 parameters. Several methods of designing digital filters from analog filters are observed and their different characteristics analyzed. Finally, a program is used to optimize a digital filter's response.

**Graphics Simulation Experiments** [NOTE: an individual account must be set up on the campus RCS system for students to have access to the Gaussian PDF program. See the instructor if you are interested in performing this experiment.] - Two programs utilizing the graphics capabilities of engineering workstations are used in detail to solve typical engineering problems. The first is a linear system block diagram transfer function simulator that is used to design a controller for a given system. The second is a probability distribution decision boundary program that demonstrates the effects of changing the parameters of a 2-dimensional Gaussian probability distribution curve on the signal's decision boundary.

**Hybrid Simulation of a Controlled System** - An analog computer is used to model a linear plant that is to be controlled digitally by the microcomputer. A proportional + integral + derivative (PID), finite settling time ripple free controller (FST) and a pole placement method controller are analyzed and compared. For the PID controller, a few different methods for calculating the 3 parameters are compared to each other.

**Analog and Digital Control of a DC Motor** - A DC motor is controlled by an analog proportional feedback controller and a dynamic feedback controller implemented on an analog
computer. The motor is also controlled digitally by the microcomputer using a Tustin approximation, minimal prototype compensator, and ripple free compensator controllers.

**Experiments in Optimal Control** - A linear quadratic regulator, both continuous and discrete, is used to control a continuous system simulated on an analog computer. This special regulator is used to minimize a specific performance index and the trade-offs encountered in the minimization procedure are analyzed.

**NOTE ABOUT LAB PC OPERATING SYSTEMS:**

The lab PCs may be booted up in one of three modes: DOS only (no Windows running in the background), Windows98, or WindowsXP, depending on the experiment is to be run.

Plain DOS is needed for the Binary Communication experiment. This experiment must be run on the older PCs (tan color) in the back row of the room. They are the only ones that still support the analog card required by the lab. If the PC is running Windows98, select **Restart (DOS Command)** and let it reboot.

If the PC is running WindowsXP, it must first be rebooted with Windows98 and then use the previous procedure to get to DOS. To get Windows98, while the PC is booting up, hit the **<F8>** key immediately after the Dell screen appears. Use the up arrow to select **Safe Mode with Command Prompt** and hit **<Enter>**. Then for Windows98, on the next screen use the down arrow key to select **Microsoft Windows** (for 98) and hit **<Enter>**.

The procedure to boot the PC without Windows running in the background must be used every time the computer is used for real-time control applications in the Computer Applications Lab experiments (Binary Communications Lab, old (non-LabVIEW) Digital Filtering Lab, and old DOS versions of the control labs – Hybrid Control, Optimal Control, & DC Motor Control). At the DOS prompt type: **CD C:\Cstudio\CAL_LAB**. A ‘dir’ command will give you a list of available directories for the different experiments to which you can move (ex. ‘cd bincomm’) to run the appropriate executable programs.

WindowsXP is used for the experiments that use LabVIEW (New Introductory Lab, New Hybrid Control Lab, New Optimal Control Lab, New DC Motor Control Lab, and New Digital Filtering Lab), as well as to run LogicWorks 5 for the Logic Design Lab and EVM30XW for the Voice Processing Lab. The default boot up of the lab PCs should be into WindowsXP.

Windows98 may optionally be used for the Voice Processing Lab and Logic Design Lab – but only for LogicWorks 4.
ECSE-4760  REAL-TIME APPLICATIONS IN CONTROL & COMMUNICATIONS

Preferential Choice of Labs for Semester

If you are keeping the same Lab Partner throughout the term, put both names on one sheet.

NAME: __________________________________ (RCS) E-mail: ______________________________

Lab Section: 1  ____________________________ Lab Days: MTWR  ________________ Lab Time: will vary

Below are listed the remaining 8 experiments after the introductory experiment. In the space after the name, indicate your preference to do that lab (1 = Highest preference, 8 = Lowest preference). Labs with equal preference may be given the same number. We will try to schedule everyone for their first five choices. The lower choices will be used only under extreme conditions.

Please turn in this sheet in lecture or to the TA in your lab section by Thursday of the second week of classes. If you do not turn in a sheet, you will be scheduled for labs at the TA's discretion.

The class LMS page or your e-mail address will be used by the TAs and instructor for class announcements and individual messages. Please check both regularly.

Digital Logic
Voice Processing
Binary Communications
Digital Filtering
Graphics Simulations [Will optionally use created AFS accounts.]
Hybrid Control
DC Motor
Optimal Control

NOTE: In addition to the regularly scheduled Lecture/Lab times MR 12:00-1:50pm, there will be weekly flexible Open Shop times to work on lab experiments T 5:00-7:00pm and W 8:00-10:00am.