ECSE-4760
Real-Time Applications in Control & Communications

COURSE INTRODUCTION

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1.0 INTRODUCTION

Because of the increasing emphasis placed upon the use of computers in the design and development of automatic control and communication systems, this laboratory is dedicated to the computer processing of signals, and is centered about the Pentium PC digital microcomputer. The goal of the laboratory is to develop the student's ability to define and solve realistic engineering problems, arising in the applications of computers to automatic signal processing.

Lectures and experiments have been designed to make the student aware of some of the features that have resulted in the increasing application of digital computers to signal processing, namely:

   a) The processing speeds, sample frequencies, and throughput capabilities of microcomputers.
   b) The capability of storing and accessing large amounts of data on peripheral devices.
   c) The relative ease of synthesizing a wide class of nonlinear operations.

Furthermore because these features can now be obtained at relatively low cost through the use of a microcomputer, the experiments utilize the Electrical, Computing and Systems Engineering Department's PC Computers.

1.1 Microcomputer Usage and Applications

The general trend towards smallness as exemplified by microminiaturization and VLSI, and high speed digital circuits has contributed to and been reflected in specific trends in individual fields. One such example is the increased manufacture and use of microcomputers.

The term microcomputer has been difficult to define rigorously, but it is generally accepted that the MICRO aspect of the computer refers to its size and/or price, but not necessarily to its capability. A general-purpose programmable digital computer that is "small" in size (desk top or rack mountable) and costs between $500 and $8,000 for the CPU (Central Processing Unit) usually has this prefix assigned to it. There are presently more than 50 manufacturers offering hundreds of models of microcomputers in hundreds of thousands of installations.

A typical microcomputer has a cycle time of approximately 1 to 5 nsec, a memory capability of a few MB expandable to a few hundred MB in most cases, a word length of 8 bits to 32 or 64 bits, and can be programmed in assembly language or FORTRAN, etc. In these respects it appears similar to the larger computers. However, the microcomputer has certain features that make it uniquely applicable as an on-line element of a system. Generally, in these applications of microcomputers the input and output of data is a dominant factor, and the computer is required to exhibit high throughput rates. It might be said that the special features of the microcomputer are all designed to meet this end.

Manufacturers have concentrated on providing special input-output devices and displays which ease the interface between the computer and the outside world as well as increasing the overall throughput. High speed internally or externally triggerable A/D (Analog to Digital) and D/A converters are commonplace to provide the microcomputer compatibility with the analog signal domain and associated transducers, while interactive graphic displays are popular for providing effective interface with the human operator. Typical of the options that are offered to directly increase the throughput of the microcomputer are ROMs (Read Only Memories) and DMA (Direct Memory Access). The read only property enables ROMs to operate at cycle times in the general range of 25 to 500 nsec, a gain of speed of from two to eight times that of the mainframe memory. DMA is used when data must be transferred
quickly. This unit is able to pass data directly between memory and an external device without intervention of the program that is being executed.

The advantages to the student or engineer are the complete control over the microcomputer at both the hardware and software level, the ease of interface of the micro with typical analog signals, and the micro's high throughput capability. Many times, it is more appropriately used as and compared to a piece of laboratory test equipment than to a large general-purpose computer. The computer is easily tied to other electronic equipment, and computer hardware modifications are possible. Programming is usually done in assembly language for highest speed (C and FORTRAN are available at increasingly lower speeds). Real time on-line operation is thus a reality, and the computer can be used as an integral part of a laboratory instrument or process controller.

As a further comparison, the main computer facility at Rensselaer utilizes a large mainframe IBM general purpose computer. Extensive software includes an operating system, compilers (C, FORTRAN, PL/1, ALGOL, COBOL, LISP), assemblers, applications programs, and library subroutines. The student does not interface with the machine directly, and when interaction does exist (remote terminal access), real time on-line capability does not. No control over the hardware is possible and compatibility with analog signals etc. is not available. It should be emphasized, however, that the large general-purpose computer and microcomputer are not in competition for student usage for they each serve their own class of problems.

Microcomputer projects offer the student something much more than computer programming. He is not only acquainted with real time on-line applications, but is permitted to become involved with computer hardware, software and overall sampled data system design involving a computer as an elemental block.

1.2 Features of the Laboratory Microcomputer

The microcomputers used for this laboratory is a Pentium PC having 1 nsec, 32-bit data bus 64 M byte memory. Peripherals include a VGA display, a 2 G byte hard disk drive, and a printer.

External analog signals can be transmitted to the computer through an A/D converter which provides the conversion and controller circuitry necessary to convert analog signals to digital signals for 4 analog channels with 12-bit resolution, including "Sign", on a ±10V to +10V analog input. The channels may be selected individually under program control.

In turn, computer processed data can be transmitted to external devices through two D/A converters which provide a fully interfaced conversion of digital data to bipolar analog data, with a resolution of 12 bits available on a ±10V to +10V volts analog output. The device may be operated individually, and conversion is under program control.

Facilities for logical input and output are provided through a digital keyboard encoder and a VGA display. The keyboard supplies the capability for sending to the computer commands and numerical values for different parameters while the display is used to output numerical values, code words, graphics, and to prompt the user for the next inputs.
2.0 LABORATORY CONFIGURATION AND OPERATION

At present there are five individual laboratory experimental stations (to be referred to as lab benches) each being a Pentium PC microcomputer. Each experimental program has its own routines to handle the keyboard, flat panel display and A/D and D/A converters. The main program for each experiment resides on the PCs hard disk. These programs, written in 'C' or LabVIEW for maximum efficiency, perform the specific computation and data transfer operations required for each experiment. Some experiments utilize an attached DSP board for higher processing performance. Data for these programs are however to be supplied by the student via the lab bench in the manner defined by the experimental directions.

Facilities at each lab bench include:

- PC 101 key Keyboard
- Color Flat panel Display
- A/D Inputs (10 per bench, 3 per bench for Binary Communication Lab))
- D/A Outputs (2 per bench)
- Printer (parallel port LPT1:)
- RS-232 (2 serial ports COMn:)
- USB Ports
- Floppy & Hard disk drives
- Oscilloscope, D.C. Power Supply, Adjustable Low-Pass Filter, Function Generator, ...

At the start of the laboratory session the students will execute the specific laboratory experiment program on hard drive C:\RTA_LAB of the PC. Executable programs for each experiment are found in sub-directories that are named after the particular experiment. When started, each program will interrogate the keyboard for communication with the student at the laboratory bench. Output may be sent to the display, converted to special analog levels by the D/A converters, or sent to the disk, printer, or serial port.

Normally the experiment would expect certain variables to be set via the keyboard. Using some form of function and value encoding, the experimental parameters would be set, and any processing initiated. All communication with the laboratory bench will be under control of the laboratory experiment program.

3.0 LABORATORY PROCEDURE

Due to the complexity of the laboratory set-ups, problems are encountered occasionally in using the equipment. Since this is a senior level lab course, the students are expected to trouble-shoot equipment problems and assist the T.A.'s in locating and correcting any obstacles encountered (i.e., defective BNC cable or nonfunctioning amplifier).

3.1 Format

The course format consists of two one-hour lecture periods and two 3-hour laboratory sessions each week. Lecture attendance is essential in that coverage will be given to specific experimental procedures, experimental background, and laboratory changes. Two quizzes will also be administered at those sessions specified in the Lecture Schedule that you should have in your possession.
At present, six individual two-week experiments are planned according to the Laboratory Schedule that you should also have obtained. During the first week, students should meet in their respective sections for assignment of lab partners and a general introduction to the laboratory. The next week and a half will be devoted to an introductory experiment that all students will be performing simultaneously. This will be followed by five two-week (i.e., 4 sessions) experiments dealing with various aspects of communication and control. Several experiments are project and design oriented.

It is recommended that students who have not had control courses (ECSE-2410 Signals & Systems) defer the control experiments until after the last control-oriented lectures. Similarly, students who have not had ECSE-4520 Communication Systems should defer the digital filter and binary communication experiments until after the related lectures.

3.2 Laboratory Report Requirements

The reports should be prepared neatly and orderly on a word processor with the raw experimental data included as an appendix. The data should be recorded in a loose-leaf laboratory notebook in the lab. Bound lab notebooks are not required (and not recommended). Each report must contain the following items:

a) Name, Title of experiment, dates performed, names of partners, bench number, section number, and time of lab session on a title page.

b) Objective: one or two statements clearly indicating the purpose of the experiment as the student interprets it.

c) Equipment description including type of instrument, manufacturer, model, serial or lab number.

d) Block diagram showing experiment and computer interfaces.

e) Procedures followed.

f) Calculations needed to perform experiment when appropriate.

g) Results: data tables, oscilloscope screengrabs (record enough for all partners if possible; otherwise include a photocopy), hand drawn graphs, etc.

h) Discussion of contradictory data and inappropriate conclusions if necessary. Anticipated results and conclusions can be included here in the event of equipment failure.

i) Conclusions based upon the results.

j) Critique of experiment.

3.3 Laboratory Report Format

The following is a sample format that you may use as a model for your reports.
OBJECTIVE: The objective of your experiment should be stated clearly and concisely, in one or several sentences.

Example: The purpose of this experiment was to determine whether measurements of the changes in air-to-earth potential gradient could be used as a reliable and practical method of predicting local thunderstorms.

EQUIPMENT USED: Do not give details that are common knowledge in your field. Provide information of particular interest, such as the brand name and model of complicated apparatus or unusual equipment (e.g., Oscilloscope -- Tektronix - Model 561B-CRO-158, Serial # XXXX).

PROCEDURE: For our purposes, it is sufficient that you state the source of the procedure that you have used. If you deviated from the given procedure, describe the procedural changes you made.

If you were documenting your research for audiences that were not familiar with the procedure, then you would need to state the procedure fully, in chronological order. You would provide enough information so that another researcher in your field could use your description to replicate the experiment.

RESULTS: Provide a sample calculation, using one complete set of data. Give the results of the calculations for the rest of your data. It is not necessary to recopy your raw data from the page where you first recorded it. Refer to it as necessary, pointing out trends and identifying special features.

State the results of your experiment clearly. Figures, graphs and tables may help to support your claims, but do not rely upon them exclusively to convey essential information. Any figures or tables used should be labeled and given a reference number (e.g., Figure 1, Input Frequency and Capacitor Value).

State all significant results explicitly and in verbal form. Organize your paragraphs around effective topic sentences. Use short, declarative sentences for the most part, but vary sentence length for flow and emphasis.

DISCUSSION: Your discussion is the single most important part of your report. In it, you will show your reader that you understand the experiment and can interpret it. Analyze and explain your results, focusing your attention on questions like these:

What results were expected? What results were obtained? If there were any discrepancies, how can you account for them?
Do any of your results have particular technical or theoretical interest?
How do your results relate to your experimental objective(s)?
How do your results compare to those obtained in similar investigations?
What are the strengths and limitations of your experimental design?
If you encountered difficulties in the experiment, what were their sources? How might they be avoided in future experiments?

CONCLUSION: The body of your report should end with a brief concluding statement, similar to an abstract, which summarizes the significant aspects and results of your experiment. It should tell the reader why the experiment is significant and what implications its results have for your field of study. If your experiment confirms or contradicts an established principle or theory, this should be clearly stated. In the plainest terms, your conclusion should answer the question, "So what?"

BACKGROUND MATERIAL: Include references for your sources of information as appropriate.
3.4 Laboratory and Grading Policies

1. Lab reports should be approximately 6-8 pages in length (typed, including equations, graphs, and tables but not appendices). Any input beyond page 10 may be ignored. Include your scanned, filled-in copy of page 9 with T.A. signatures after the title page in every report. **It is your responsibility to make sure your T.A. signs this sheet after every lab session.**

2. The lab report should follow the format above (don't forget the title page). The first report (Introductory Experiment) may be handwritten but the rest should be prepared on a WORD PROCESSOR, with the exception of some math equations. Labs not prepared this way will be penalized 10%.

3. Reports are due 5 days from the last day of the experiment, i.e., on Mondays for Mon-Thurs groups (and on Tuesdays for Tue-Fri groups) or on the following Monday if the fifth day falls on a weekend/vacation. **The reports must be signed and dated by a T.A. when handed in. You are responsible for getting this signature.** Late lab reports will be **PENALIZED 2% PER DAY.**

4. Reports will be evaluated for TECHNICAL CONTENT as well as GRAMMAR, SPELLING, STYLE, AND LITERACY. You are urged to utilize the services of the Speaking & Writing Center. Its hours can be found on the web: Center for Global Communication+Design: https://info.rpi.edu/comm-d.

5. **ALL RAW DATA MUST HAVE AN ORIGINAL SIGNATURE OF YOUR LAB T.A.** (with the due date on the last page) and scans of the pages appended to your report. Include a scan of your filled-in page 9 of this handout (copies available in lab) with every report after the title page.

6. Everyone must hand in his/her own original report for the Introductory Lab. No credit will be given for copied labs. After the Introductory Lab, students may work in teams of no more than 2 members and hand in a single report for the team.

7. **All labs are due by the final deadline: the last day of classes of the semester.** All missing labs at this time will be given a grade of ZERO.

Absences:

1. T.A.'s should be informed of plant trips BEFORE they take place. A make-up lab should be scheduled. If you are making up the lab in another section, you should obtain a note from your T.A. allowing you to work in the other lab.

2. Other valid reasons for being absent from lab are: a note from the DEAN OF STUDENTS, the INFIRMARY, an ROTC OFFICER, or a VARSITY COACH.

3. No make-ups for quizzes will be given without a valid excuse. A grade of zero will be assigned.

4. Make-ups may be scheduled outside lab hours with a T.A.'s consent. However, a T.A. must be present or available in the lab during a make-up session.

5. All excuses must be received within two weeks of the absence in order to be accepted.
**COURSE GRADING:**

<table>
<thead>
<tr>
<th>LAB REPORT:</th>
<th>1. TECHNICAL CONTENT</th>
<th>75%</th>
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<tbody>
<tr>
<td></td>
<td>2. STYLE, LITERACY AND GRAMMAR</td>
<td>25%</td>
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<tr>
<th>COURSE:</th>
<th>1. LAB REPORTS (6)</th>
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<td>2. LAB PREPARATION &amp; PERFORMANCE</td>
<td>10%</td>
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<td></td>
<td>3. TESTS (2 - #1 for 15% and #2 for 25%)</td>
<td>40%</td>
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**Preparation & Performance Measures:**

1. Attendance/tardiness.
2. Experimental procedure and laboratory techniques.
3. Questions asked.
4. Responses to T.A. questions about the experiment.
5. Ability to complete experiment in allocated time.
6. Pre-lab and preparation work.
Report Grade Form: (to be turned in with every experiment report)

<table>
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<th>NAME:</th>
<th>EXPERIMENT:</th>
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**TECHNICAL CONTENT (75%)**

A. Calculations and Graphs /15%
B. Analysis and Discussion /50%
C. Conclusions /10%

**STYLE AND LITERACY (25%)**

A. Neatness /5%
B. Literacy /10%
C. Format and General Organization /10%

**COMMENTS:**

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<tr>
<th>T.A.:</th>
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<th>GRADE:</th>
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Dates Performed T.A. Signature

1. __________

2. __________

3. __________

4. __________

5. __________

6. __________

Date Report Handed In

___________ ___________ (Days Late: _____)
Section 3.4 of the COURSE INTRODUCTION is posted as a reminder of the main laboratory procedure and grading policies in effect.
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