COURSE TITLE:

Basic Principles of Analog and Digital Signal Processing including Hands-on Laboratory Experiments (Part 1)

Dates: *November 2003*
Course location: ....
Lecturer: *Jean-Paul Sandoz, Professor of Electronics and Signal Processing*

FORWORDS:

- *Computer simulations, when properly applied, provide a great deal of insight into a problem of interest, but they are* ***no substitute for tests with real-life data****. It is therefore not surprising that many algorithms fail to survive the ″test of time″.*

- *Without question, mathematics is a powerful tool that gives an algorithm both elegance and general applicability. By the same token, however, an algorithm that* ***ignores physical reality*** *may end up being of* ***limited*** *or* ***no practical use****.*

- ***Signal processing is at its best*** *when it successfully combines the unique ability of mathematics to generalize with both the insight and* ***prior information*** *gained from the underlying physics of the problem at hand.*

IEEE Signal Processing Magazine
Simon Haykin, McMaster University
Hamilton, Ontario, Canada

COURSE OBJECTIVES

To equip the participant with a ***simultaneous*** theoretical and practical signal processing (analog and digital) background. A specific emphasis will be placed upon connecting:

- Real signals coming from real sources (e.g. ultrasound transducers)
- Analog pre-processing (i.e. preamplifier and pre-filtering with OPAMPs)
- Analog-to-digital conversion with a handy *Data-Acquisition System* (Pico adc-212)
- Basic signal processing and mathematical analysis (Simulation software ″SystemView″).
- Data Acquisition with Impulse Response and Frequency Response
- Time-Delay Estimation with Fourier Transform

Teaching methodology:

50 to 75% hands-on laboratory experiments

ORGANIZATION OF THE COURSE

Day 1 Continuous Signal and System Analysis

Theory
- Introduction to Signal Processing ***Chap 1***
- Linear System Steady-State Response ***Chap 2***
- Linear System Response (general case) ***Chap 3***

Practice
- Review: Oscilloscope, Generator; Probe ***Lab #2, Basic..***
- Steady State Response with R-C and R-L-C filters ***Lab #1, Chap2***
- Transient response (Impulses, Step, Chirp, On-Off Carrier) ***Lab #1-2,Chap 3***

Day 2 Basic DSP Theory

Theory
- Sampling, A-to-D and D-to-A Conversion ***Chap 4***

Practice
- Introduction to ″PICO″ as a digital scope, Aliasing ***Lab #1-2;Chap 4***
- Signal Acquisition, Impedance Measurement ***Lab #5-6;Chap 4***

Day 3 Digital Signal Processing

Theory
- The Z Transform, Applications of the Z Transform ***Chap 5, Chap 6***
- Digital Filter Design: Basic principles and examples ***Chap 7***
- Discrete Fourier Transform (DFT), FFT ***Chap 8***

Practice
- Periodic Signals → PICO → FFT or SystemView → FFT ***Lab #1-2-3;Chap 8***
- Digital Filtering (SystemView)
- Real Signal → PICO → SView → FFT → Frequency Response ***Lab #5;Chap 8***
- Real Signal → PICO → SView → FFT → Time-Delay Estimation ***Lab #6;Chap 8***

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Basic Measurement Review

Laboratory #1 – *Voltmeter, Ammeter, Ohm-meter*

- Be able to measure ″DC Voltage″ , ″DC Current″ and ″Resistors″ with a multimeter.
- Apply and verify with practical examples ohm’s law.
- Determine the dissipated power into resistors and build a simple LED circuit.

Laboratory #2 – *Analog Oscilloscope*

- Identify the most important control knobs of an analog scope.
- Display signals in a usable form (i.e. amplitude, period, synchronization).
- Understand the importance of the various ″Synchronization modes″

Chap 2 - Linear System Steady State Response

Laboratory #1

- Be able to measure ″Amplitude″ and ″Phase″ response of a linear circuit with an oscilloscope.
- Understand the difference between parallel and series resonance.
- Build and characterize an R-L-C circuit modeling an ultrasound transducer.

Laboratory #2

- Demonstrate ″Periodic Signal Decomposition″ into ″Fourier Series″ with a practical example.

Laboratory #3

- Understand the impact of non-linearity.

Laboratory #4

- Be able to determine theoretically, by computer simulation (EWB) and practically the output y(t) of a linear system if its input signal x(t) is periodic.

Chap 3 - Linear System Response: general case

Laboratory #1

- Understand the difference and the relationship between a step and impulse response.
- Determine the limits of validity of an approximated impulse response.

Laboratory #2

- Apply the Laplace Transform theory in a practical example.
- Understand the relationship between a filter bandwidth and its rise and/or fall time (transient mode)

Laboratory #3

- Understand multiplication in the time domain and the corresponding convolution in the frequency domain.
- Verify that the product of two periodic signals generates sums and differences of frequencies contained in the periodic signals.

Laboratory #4

- Understand *″Frequency down-conversion″*.
- Verify that *″undesired frequencies (e.g. mirror image)″* can also convert down to *base-band.*

Chap 4 - Sampling, A-to-D and D-to-A Conversion

Laboratory #1

- Understand the difference between ″PicoScope″ and an ″Analog Scope″
- Choose correctly the timebase, voltage range and triggering (synchronization).

Laboratory #2

- Illustrate ″Under Sampling″

Laboratory #3

- Understand ″*Narrow-band*″ signal down-conversion by under-sampling.

Laboratory #4

Laboratory #5

- Collect blocks of data in view of processing them off-line.
- Choose correctly the parameters of the PicoLog

Laboratory #6

- Collect data in view of computing the complex impedance of a R-L-C circuit.
- Choose correctly the parameters of the PicoLog

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Chap 8 - Discrete Fourier Transform (DFT), FFT

Laboratory #1

- Understand the impact of ″integer″ or ″non-integer″ number of periods of a periodic signal in the ″sampling window″.
- Relate ″DFT fundamental frequency″ and ″frequency resolution″ to ″sampling rate″ and ″number of samples″.

Laboratory #2

- Understand the advantages and disadvantages of *″windowing″*.

Laboratory #3

- Compare the advantages and drawbacks of various "windows"

Laboratory #4

- Optimum ″window″ type selection

Laboratory #5

- Linear circuit impulse response (approximation) recording.
- ***″Amplitude″*** and ***″phase″*** characteristics estimation (DFT).
- Introduction to ***″SystemView″.***

Laboratory #6

- 40 kHz ultra-sound transmitter-receiver impulse response measurement.
- Time delay estimation from DFT (FFT) phase computation.

LECTURER

Jean-Paul Sandoz graduated from the Engineering College of Canton Neuchâtel and received the Master of Applied Sciences degrees in Electrical Engineering from Ottawa University, Canada.
He worked at the Observatory of Neuchâtel, Switzerland, on digital synchronous receivers, digital PLL and geophysical instrumentation. He also worked with EDA Instruments Inc., Toronto, Canada as development engineer and later, he was a member of the research staff with Sodeco-Saia, Geneva, Switzerland. He is presently Professor of Analog and Digital Signal Processing at EIAJ, Western Switzerland University of Applied Sciences. His teaching and research interests include applied DSP techniques to weak signal detection and classification, low-noise analog front-end, "One-bit" DSP techniques with applications to Phase/Frequency Detectors, Time Delay Estimators and Multiple Pulse Response Technique. He is currently active in "Hilbert Transform" Real-Time Digital Applications. He gave several DSP seminars including one in Ujung Pandang, Indonesia.