EE4C05 Digital Signal Processing [5 credits]

Lecturer:  Dr. W. Dowling  wdowling@tcd.ie

Module organisation
Semester 1: 3 lectures and 1 tutorial per week. 4 associated laboratories.

Module description, aims and contribution to programme
Digital Signal Processing (DSP) is concerned with the processing of signals that are represented as sequences of finite-precision numbers. This course is an introduction to the theory and applications of digital signal processing. The DSP laboratory exercises are an integral part of the course and contribute to an enriched understanding of the theoretical material covered in the lectures.

Learning outcomes
On successful completion of this module the student should be able to:

1. Design FIR filters using the window and frequency sampling methods
2. Design IIR filters to meet detailed gain specifications, via the bilinear transformation
3. Implement digital filters in Matlab observing computational constraints (pipeline and parallel flows)
4. Design decimation and interpolation systems for discrete-time signals
5. Design discrete-time systems to filter analogue signals
6. Implement linear convolution of arbitrarily-long sequences via the FFT algorithm
7. Characterise wide-sense stationary random signals and the outputs that result from LTI filtering of such signals

Module content
• Sampling and reconstruction of analogue signals
  Review of continuous-time signal and system analysis using Fourier and Laplace transforms
  Ideal impulse sampling and reconstruction of bandlimited signals
  Digital to analogue conversion, practical considerations

• Discrete-time sequences
  Discrete-time signals and systems, linearity, time-invariance, stability, causality
  Discrete-time convolution, linear constant-coefficient difference equations, magnitude and phase response
  The discrete-time Fourier transform (DTFT) and its properties

• The z-transform and its properties
  The z-transform, region of convergence for the z-transform, inverse z-transform, z-transform properties
- **FIR filter design**
  - Generalized linear-phase causal FIR filters
  - FIR linear-phase filter design using the window method
  - Frequency-sampling design of FIR filters

- **IIR filter design**
  - IIR filter design using the bilinear transformation
  - Filter design by impulse invariance

- **Realization of digital filters**
  - Signal flow graph representation of linear constant-coefficient difference equations
  - Basic network structures for implementing FIR and IIR digital filters

- **The Discrete Fourier Transform**
  - The discrete Fourier transform (DFT), properties of the DFT
  - Circular convolution
  - Linear convolution via the DFT and the overlap-add method
  - The radix-2 decimation-in-time fast Fourier transform (FFT) algorithm

- **Changing the sampling rate using discrete-time processing**
  - Sampling rate reduction by an integer factor
  - Increasing the sampling rate by an integer factor
  - Changing the sampling rate by a noninteger factor

- **Discrete-Time Random Process**
  - Mean and variance of a random variable; autocorrelation and autocovariance functions; cross-correlation and cross-covariance functions; wide-sense stationary random signal; ergodic process; power density spectrum.
  - Response of linear systems to random signals

**Teaching strategies**
The module is taught using a combination of lectures, tutorials and supporting laboratories

**Assessment**
70% of the final mark is determined via the annual two-hour written examination, and the remaining 30% via two in-class tests.

**Recommended textbook**

**Further information**
https://www.tcd.ie/Engineering/undergraduate/baiyear4/