# Pengolahan Sinyal Digital

Adhi Harmoko Saputro

# Tujuan

- Mampu menjelaskan sistem pengolahan digital
- Mampu melakukan pemrosesan sinyal dalam domain waktu diskrit dan frekuensi diskrit
- Mampu menerapkan pengolahan digital untuk aplikasi filter digital

# Silabus

- Pengenalan sinyal-sistem
- Konversi sinyal analog ke digital dan sebaliknya
- Sinyal waktu diskrit
- Transformasi Z dan penerapannya untuk sistem linear invarian waktu (LTI)
- Analisis frekuensi sinyal waktu kontinu dan analisis frekuensi sinyal waktu diskrit
- Transformasi Fourier untuk sinyal waktu diskrit
- Konsep filter, filter digital FIR, IIR, penerapan filter digital

# Buku Referensi


- Digital Signal Processing Using MATLAB® Third Edition, *Vinay K. Ingle*, *John G. Proakis*, Northeastern University, 2012
- Digital Signal Processing: System Analysis and Design, *Paulo S. R. Diniz*, *Eduardo A. B. da Silva and Sergio L. Netto*, Cambridge University Press, 2002
- Digital Signal Processing using MATLAB and Wavelets, *Michael Weeks*, Infinity Science Press LLC, 2007
- Fundamentals of Digital Signal Processing using MATLAB, *Robert J. Schilling and Sandra L. Harris*, Cengage Learning, 2012
- Digital Signal Processing: Principles, Algorithms and Application, *John G. Proakis*, *Dimitris K Manolakis*, Prentice Hall, 2012

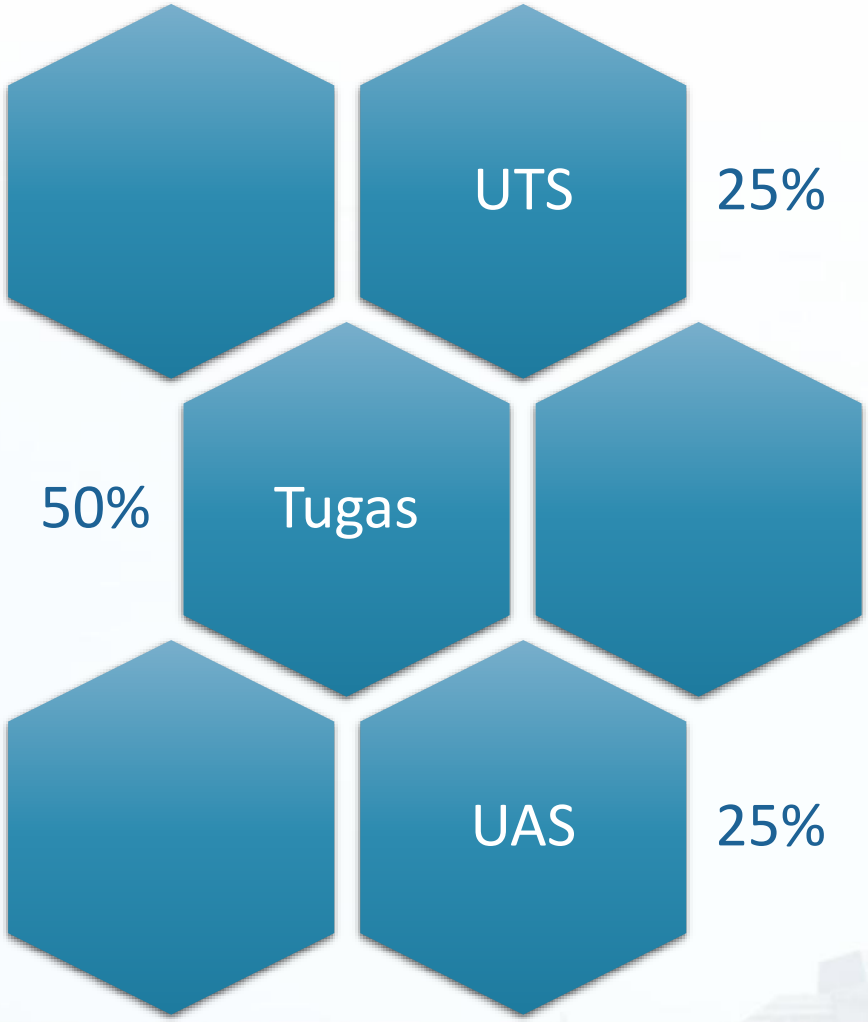
# Prasyarat

- Fisika Modern
- Fisika Matematika 2
- Elektronika 2
- Komputasi Fisika
- Matlab Programming

# Instrumen Evaluasi

- Tugas
- Ujian Tengah Semester
- Ujian Akhir Semester

# Komponen Nilai



# Kisaran Nilai

| Nilai | Grade |
|---|---|
| ≥ 85 | A |
| 80 – 84.9 | A- |
| 75 – 79.9 | B+ |
| 70 – 74.9 | B |
| 65 – 69.9 | B- |

| Nilai | Grade |
|---|---|
| 60 – 64.9 | C+ |
| 55 – 59.9 | C |
| 50 – 54.9 | D |
| 40 – 49.9 | |
| 0 – 40 | E |

# Aturan Kelas

- Hadir paling lambat 15 menit setelah kuliah dimulai
- Tidak boleh memakai sandal jepit
- Tidak boleh mencontek. Tertangkap mencontek akan diberi nilai E.
- Tugas harus dikerjakan dan dikumpulkan tepat pada waktunya. Tidak mengerjakan dan/atau tidak mengumpulkan tugas pada waktunya mendapatkan nilai nol untuk tugas terkait, kecuali sakit dengan surat keterangan dokter.
- Tidak mengikuti presentasi di kelas mengakibatkan nilai terkait presentasi tadi sama dengan nol, kecuali sakit dengan surat keterangan dokter.

# Introduction to DSP

Adhi Harmoko Saputro

# Signal, System, Signal Processing

- Signal
  - A signal is a function of independent variables such as time, distance, position, temperature and pressure
  - Signals play an important role in our daily life. Most signals we encounter are generated naturally.
    - However, a signal can also be generated synthetically or by a computer.

# Signal, System, Signal Processing

- Depending on the nature of the independent variables and the value of the function, we can classify the signals as follows
  - Scalar signal
    - A signal generated by a single source
  - Vector signal (or multichannel signal)
    - A signal generated by multiple sources
  - One dimensional (1-D) signal
    - A function of a single independent variable
  - Multidimensional (M-D) signal
    - A function of more than one independent variables

# Signal, System, Signal Processing

- Continuous-time signal $x(t)$
  - The independent variable is continuous
- Discrete-time signal (sequence) $x(n)$
  - The independent variable is discrete
- Analog signal
  - A continuous-time signal with a continuous amplitude
- Quantized-boxcar signal
  - A continuous-time signal with a discrete-value amplitude
- Digital signal
  - A discrete-time signal with a discrete-value amplitude
- Sampled-data signal
  - A discrete-time signal with a continuous amplitude

# Signal, System, Signal Processing

- Deterministic signal
  - A signal that can be uniquely determined by a well-defined process, such as a mathematical expression or rule, or table look-up.
- Random signal
  - A single that is generated in a random fashion and cannot be predicted ahead of time.

# Signal, System, Signal Processing

- Periodic signal
  - A signal that repeats itself in a periodic fashion from negative to positive infinity.

$$x(t) = x(t + kT)$$

$$x(n) = x(n + kN)$$

- Aperiodic signal
  - A signal that extends to both positive and negative infinity without repeating in a periodic pattern.

# Signal, System, Signal Processing

- Power signal
  - An infinite energy signal with finite average power.

$$P = \lim_{T\to\infty} \frac{1}{T} \int_0^T |x(t)|^2 \, dt < \infty \qquad P = \lim_{N\to\infty} \frac{1}{N} \sum_{n=0}^{N-1} |x(n)|^2 < \infty$$

- Energy signal
  - An finite energy signal with zero average power.

$$E = \int_{-\infty}^{\infty} |x(t)|^2 \, dt < \infty \qquad E = \sum_{-\infty}^{\infty} |x(n)|^2 < \infty$$

  - a periodic sequence — power signal
  - a finite-length sequence — energy signal

# Signal, System, Signal Processing

- System
  - A system is any process that produces an output signal in response to an input signal.

# Signal, System, Signal Processing

- Depending on the types of the signal processed, we can classify the systems as follows:
  - Analog input – analog output
    - Digital recording of music
  - Analog input – digital output
    - Touch tone phone dialing
  - Digital input – analog output
    - Text to speech
  - Digital input – digital output
    - Compression of a file on computer

# Signal, System, Signal Processing

- Depending on the types of the signal processed, we can classify the systems as follows:
  - Continuous-time system
    - input and output continuous-time signals
  - Discrete-time system
    - input and output discrete-time signals

# Signal, System, Signal Processing

- Signal Processing
  - A signal carries information !

- The objective of signal processing:
  - To extract, enhance, store and transmit the useful information carried by the signal.

# Signal Processing

- Humans are the most advanced signal processors
  - speech and pattern recognition, speech synthesis,…
- We encounter many types of signals in various applications
  - Electrical signals: voltage, current, magnetic and electric fields,…
  - Mechanical signals: velocity, force, displacement,…
  - Acoustic signals: sound, vibration,…
  - Other signals: pressure, temperature,…
- Most real-world signals are analog
  - They are continuous in time and amplitude
  - Convert to voltage or currents using sensors and transducers

# Signal Processing

- Analog circuits process these signals using
  - Resistors, Capacitors, Inductors, Amplifiers,…
- Analog signal processing examples
  - Audio processing in FM radios
  - Video processing in traditional TV sets

# Limitations of Analog Signal Processing

- Accuracy limitations due to
  - Component tolerances
  - Undesired nonlinearities
- Limited repeatability due to
  - Tolerances
  - Changes in environmental conditions
    - Temperature
    - Vibration
- Sensitivity to electrical noise
- Limited dynamic range for voltage and currents

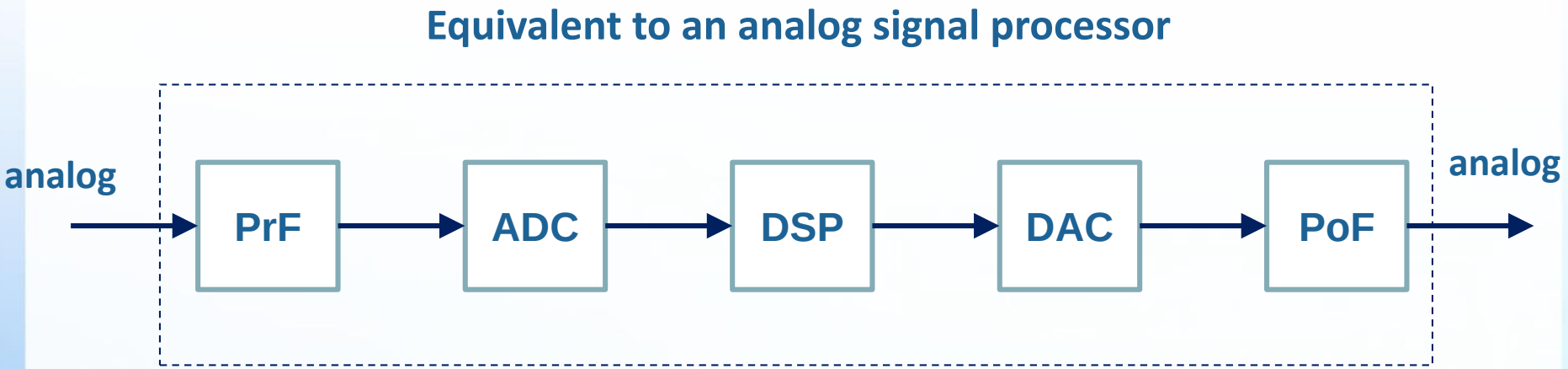
# Limitations of Analog Signal Processing

- Inflexibility to changes
- Difficulty of implementing certain operations
  - Nonlinear operations
  - Time-varying operations
- Difficulty of storing information

# Digital signal processing

- Represent signals by a sequence of numbers
  - Sampling or analog-to-digital conversions
- Perform processing on these numbers with a digital processor
  - Digital signal processing
- Reconstruct analog signal from processed numbers
  - Reconstruction or digital-to-analog conversion

# The Constitution of DSP System




PrF: antialiasing filtering

PoF: smooth out the staircase waveform

# How to Implement the DSP

- To handle the DSP algorithms in a general-purpose microprocessor by means of software programming

- To handle the DSP algorithms in a specifically designed Digital Signal Processors (DSPs)

# The Application of DSP

- The main tasks of DSP
  - Signal Analysis
    - Measurement of signal properties
    - Spectrum (frequency/phase) analysis
    - Target detection, verification, recognition
  - Signal Filtering
    - Signal-in-signal-out, filter
    - Removal of noise/interference
    - Separation of frequency bands
    - Shaping of the signal spectrum

# The Application of DSP

- DSP application examples
  - Telecommunications
    - Multiplexing
    - Compression
    - Echo control
  - Audio Processing
    - Music
    - Speech generation
    - Speech recognition

# The Application of DSP

- DSP application examples
  - Echo Location
    - Radar
    - Sonar
    - Reflection seismology
  - Image Processing
    - Medical
    - Space
    - Commercial Imaging Products

# The Application of DSP

- DSP application examples
  - Digital image processing
    - Deblurring
    - Edge detection
    - Noise reduction

# Pros and Cons of Digital Signal Processing

- Pros
  - Accuracy can be controlled by choosing word length
  - Repeatable
  - Sensitivity to electrical noise is minimal
  - Dynamic range can be controlled using floating point numbers
  - Flexibility can be achieved with software implementations
  - Non-linear and time-varying operations are easier to implement
  - Digital storage is cheap
  - Digital information can be encrypted for security
  - Price/performance and reduced time-to-market

# Pros and Cons of Digital Signal Processing

- Cons
  - Sampling causes loss of information
  - A/D and D/A requires mixed-signal hardware
  - Limited speed of processors
  - Quantization and round-off errors

# Terima Kasih