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AGRICULTURE • INNOVATION • LIFE

A Gentle Introduction to Signal Processing

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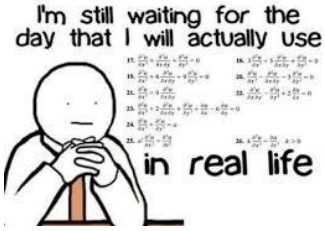


Why?

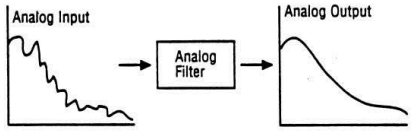
Signal Processing

Science of analyzing time-varying physical process

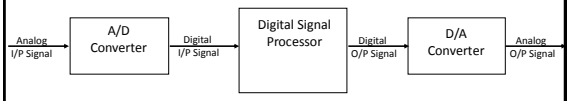
There are two categories of signal processing:

1. Analogue Signal Processing
   - A waveform that is continuous in time and can take a continuous range of amplitude values, a.k.a. continuous signal processing.
2. Digital Signal Processing
   - A digital signal, which is discrete-time-signal, is not represented by a continuous waveform and the discrete-time signal quantities.

Analogue Signal Processing

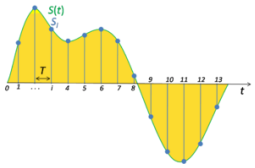


Digital Signal Processing

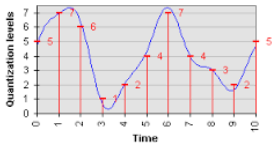


ADC

- Sampling



- Quantization

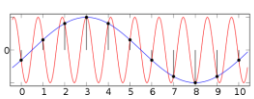


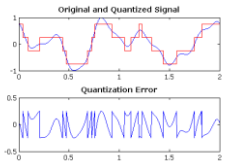
Benefits: Digital Signal Processing over Analogue Signal Processing

1. Flexibility of the system offered by the software component
2. Better control of accuracy requirements, i.e. no problem with external effects
3. Ease of storage and offline processing
4. Lower cost of processors
5. Compression and coding techniques are efficient to implement

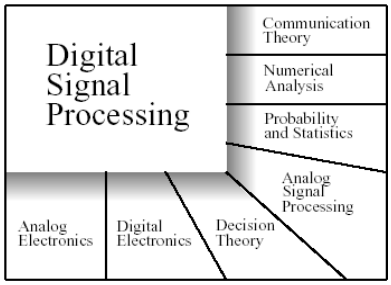
Limitations of Digital Signal Processing

- Speed of operation of digital processors
- Noise due to sampling and quantization (ADC)

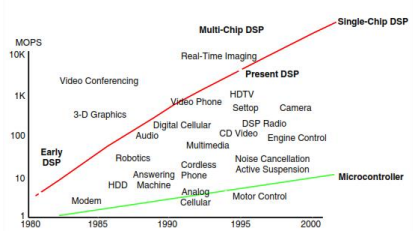




DSP in STEM



DSP As Enabling Technology (Texas)



Examples of DSP Technology

- Telecommunication
  - Multiplexing
  - Compression
  - Echo Control

- Audio Processing
  - Music
  - Speech generation
  - Speech recognition

- Echo Location
  - Sonar
  - Radar
  - Reflection Seismology

- Image Processing
  - Camera
  - Medical
  - Satellite

Multimedia Applications

- Compression: Fast, efficient, reliable transmission and storage of data
- Applied on audio, image and video data for transmission over the Internet, storage
- Examples: CDs, DVDs, MP3, MPEG4, JPEG

JPEG

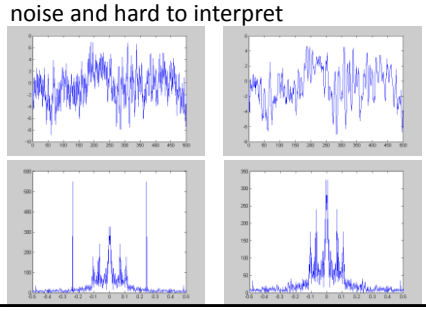
43K 13K 3.5K

- JPEG uses Discrete-Cosine Transform (similar to Fourier Transform)

Biological Signal Analysis

- Examples:
  - Brain signals (EEG)
  - Cardiac signals (ECG)
  - Medical images (x-ray, PET, MRI)
- Goals:
  - Detect abnormal activity (heart attack, seizure)
  - Help physicians with diagnosis

- Brain waves are usually contaminated by noise and hard to interpret



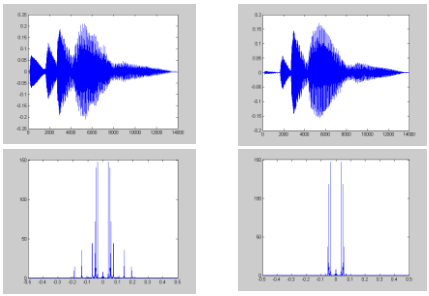
Biometrics

- Identifying a person using physiological characteristics
- Examples:
  - Fingerprint Identification
  - Face Recognition
  - Voice Recognition

Audio Signal Processing

- Active noise cancellation:Adaptive filtering
  - Headphones used in cockpits
- Digital Audio Effects
  - Add special music effects such as delay, echo, reverb
- Audio signal separation
  - Separate speech from interference
  - Wind sound from music in cars

- Filtering



Major Areas in DSP

New Algorithms in DSP

- Adaptive
- Multi-rate
- Mixed Analogue/Digital
- Non-linear

Filters

- Filters are signal conditioners
- Filter functions by accepting an input signal, blocking prespecified frequency components and passing the original signal minus those components to the output.

Digital Filters

- Lowpass- Allows only low frequency signals to its outputs.
- Highpass-Allows only high frequency signals to its outputs.
- Bandpass-Allows only output signals within its narrow, government-authorized range of frequency spectrum.
- Bandstop-Allows both low and high frequencies, but blocks a predefined range of frequencies.

Convolution

$$\mathcal{F}(f * g) = \mathcal{F}(f) \cdot \mathcal{F}(g)$$
$$\mathcal{F}(f) * \mathcal{F}(g) = \mathcal{F}(f \cdot g)$$

Programmable DSPs (P-DSP)

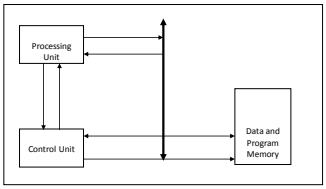
The P-DSPs are specially designed for digital signal processing application. The main components of P-DSPs are:

1. Multiplier & Multiplier Accumulator (MAC)
   - It requires array multiplication. The multiplication as well as accumulating to be carried out using hardware elements by two ways:
     - A dedicated MAC unit implemented in hardware which has integrated multiplier and accumulator in a single hardware unit.
     - Use of multiplier and accumulator separately.

2. The Processor Architecture
   - There are mainly two types of architecture of microprocessor:

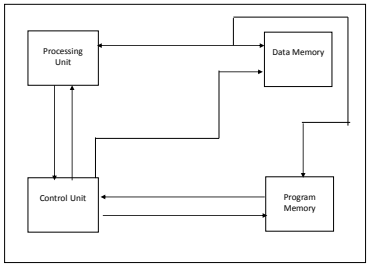
Von Neumann Architecture

- In this architecture a single address bus and a single data bus for accessing the programme as well as data memory area.



Harvard Architecture

- Separate buses for the programme and data memory



Future of Signal Processing (Texas)

Decade	Characteristic	$/MIPS
'60s	University Curiosity	$100 - $1,000
'70s	Military Advantage	$10 - $100
'80s	Commercial Success	$1- $10
'90s	Consumer Enabler	10¢ - $1
Beyond	Expected Part of Daily Life	1¢ - 10¢

Evolution of DSP Chip (Texas)

Typical Device capabilities

	1980	1990	2000	2010
Die size (mm)	50	50	50	50
Technology (uM)	3	0.8	0.1	0.02
MIPS	5	40	5,000	50K
MHz	20	80	1,000	10,000
RAM (bytes)	256	2K	32K	1M
Price	$150.00	$15.00	$5.00	$0.15
Power (mW/MIPS)	250	12.5	0.1	0.001
Transistors	50K	500K	5M	50M
Wafer size	3"	6"	12"	12"

DSP Chip for the Future

- Very low power
- High speed operation
- Reconfigurable processor
- Customizable processor
- DSP chip with multiple integer and floating point MACs

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