Digital Signal Processing
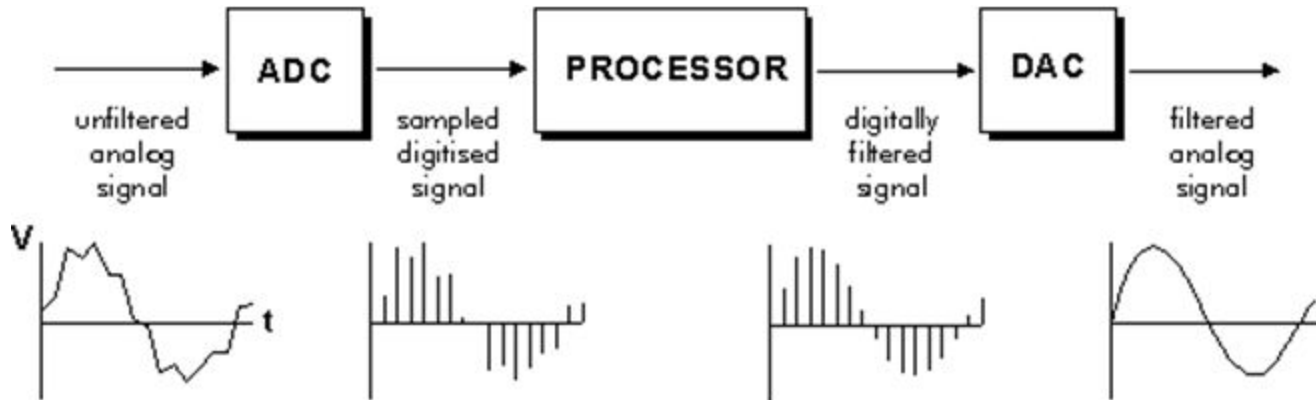
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What is Digital Signal Processing (DSP)?

- Analog-to-digital conversions
- Perform processing on these numbers with a digital processor
- Digital-to-analog conversion
- Represent signals by a sequence of numbers

What is Digital Signal Processing (DSP)?

- Analog input – Analog output
  - Digital recording of music
- Analog input – Digital output
  - Touch tone phone dialling
- Digital input – Analog output
  - Text to speech

| Analog Signal	→	ADC	→	Digital Signal Processing	→	DAC	→	Analog Signal

Why do we need a DSP?

- DSP processor is designed for high speed data-manipulation
  - Audio, comms, image manipulation, data acquisition and control
- Cannot use a general-purpose microprocessor
  - Operations done in few clock cycles (e.g. $Y=mX+C$)
- Most DSPs have a single operation
  - Does $Y=mX+C$ in one operation
- DSP will perform in a single cycle implementing all shift and add operations in parallel
  - Makes chip much more complex
  - If the DSP is not fast enough then an analogue circuit or a specialised DSP chip is required

DSP – Applications

- Sound applications
  - Compression, enhancement, special effects, synthesis, recognition
  - Cell Phones, MP3 Players, Movies, Dictation, Text-to-speech
- Communication
  - Modulation, coding, detection, equalization, echo cancellation
  - Cell Phones, dial-up modem, DSL modem, Satellite Receiver
- Automotive
  - ABS, GPS, Active Noise Cancellation, Cruise Control, Parking
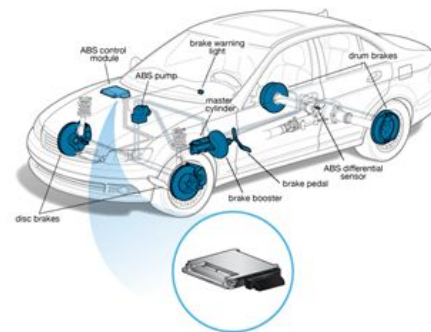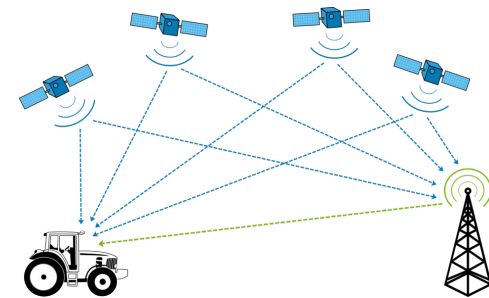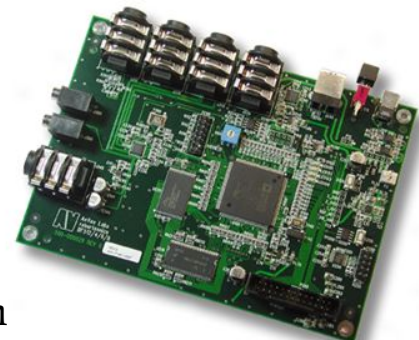
DSP – Applications

- Medical
  - Magnetic Resonance, Tomography, Electrocardiogram
- Military
  - Radar, Sonar, Space photographs, remote sensing
- Image and Video Applications
  - DVD, JPEG, Movie special effects, video conferencing
- Mechanical
  - Motor control, process control, oil and mineral prospecting
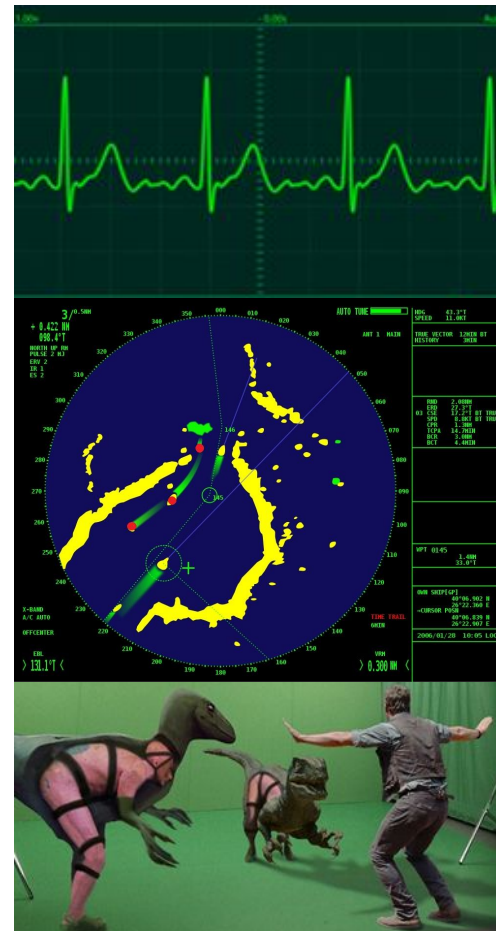
DSP – Advantages

- High accuracy
  - Digital circuits are less sensitive to tolerances of components.
- Cheaper
  - Digital circuits can be reproduced easily in large quantities at lower cost.
- Flexibility
  - DSP System can be easily reconfigured only by changing the program.
- Ease of storage
  - Digital signals are easily stored without loss of quality of signal reproduction.
- High sophistication
  - Sophisticated signal processing algorithms can be implemented easily.

DSP – Disadvantages

- Bandwidth
  - The digital communications require a greater bandwidth than analogue to transmit the same information.
- Limiting speed of processors
  - When analogue signal is changing very fast, it is difficult to convert digital form (beyond 100 KHz range).
- Loss of information
  - Information loss during sampling and quantization round-off errors.
- Non-reversible
  - When the signal is weak, within a few tenths of millivolts, we cannot amplify the signal after it is digitised.

DSP – Architecture

- DAC and ADC
- Memory
  - Holds the data and instructions to be used
- Ports
  - To communicate with other devices

- Central ALU
  - Performs the major functions – very fast
- Aux ALU
  - Maybe present and performs similar operations in parallel
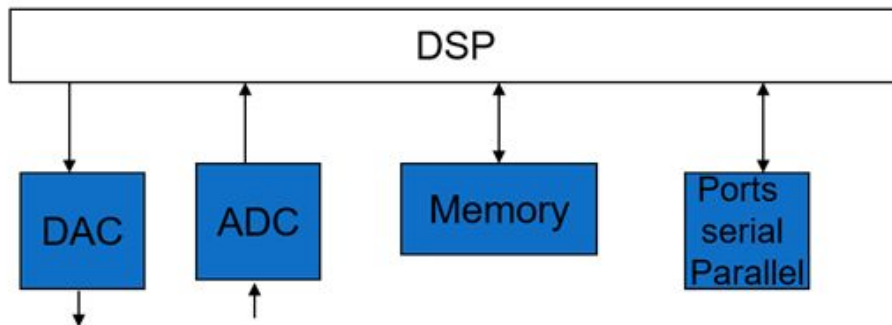
DSP – Hardware

DSPs can be purchased in three forms:

- as a core
  - In DSP, the term "core" refers to the section of the processor where the key tasks are carried out, including the data registers, multiplier, ALU, address generator, and program sequencer.
- as a processor
  - A complete processor requires combining the core with memory and interfaces to the outside world.
- as a board level product
  - These have such features as extra memory, A/D and D/A converters, EPROM sockets, multiple processors on the same board, and so on.
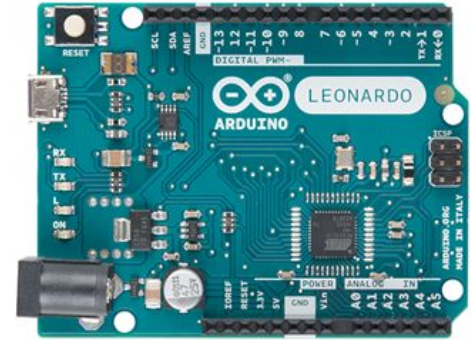
DSP – Techniques

- Most DSP techniques are based on a divide-and-conquer strategy called superposition.
- The signal being processed is broken into simple components, each component is processed individually, and the results reunited.
- This approach has the tremendous power of breaking a single complicated problem into many easy ones.
- Superposition can only be used with linear systems, a term meaning that certain mathematical rules apply.
- Fortunately, most of the applications encountered in science and engineering fall into this category.

DSP – Techniques

- There are 2 important concepts in linear systems DSP.
- Synthesis
  - Combining multiple signals through scaling and addition.
- Decomposition
  - Take one signal and break it into multiple signals.
- E.g.
  - The figure shows three signals: $x\_0\,[n], x\_1\,[n]$ and $x\_2\,[n]$ are added to form a fourth signal, $x\,[n]$.
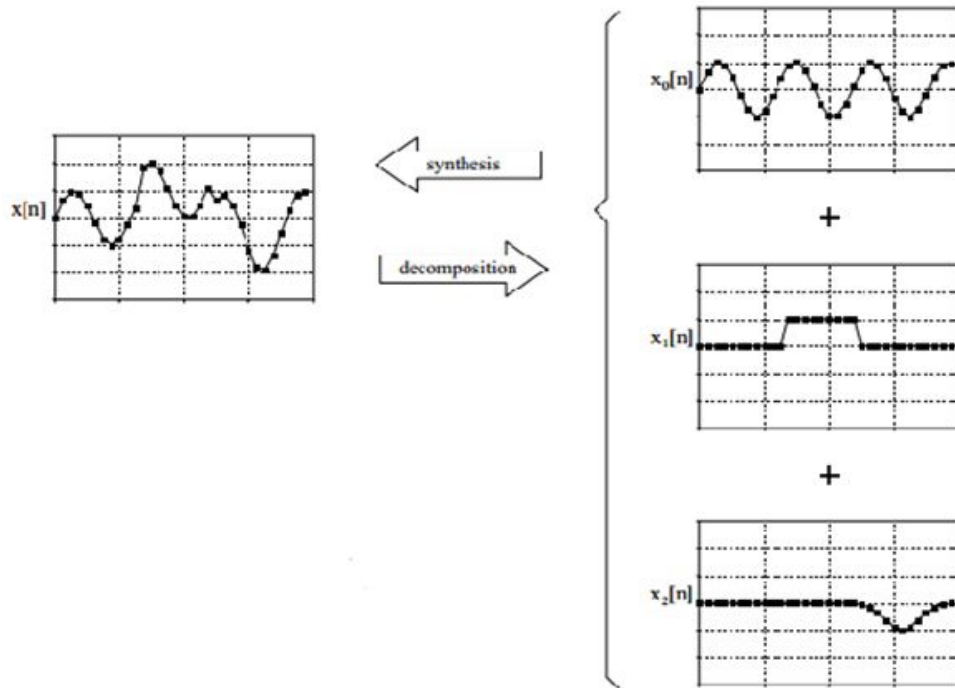
DSP – Programming

- High level language programmes easier to write
- Assembler faster execution
- Can combine both in a DSP programme
- Time critical sections in assembler
- Other sections in high level language

DSP – Tools

- Simulators
  - Software implementation of the chip
  - Used to try out programme design before a more costly implementation
- Emulators
  - Allows direct control and debug the results of instructions on a DSP
  - Emulator runs on PC but exerts control over DSP
  - Possible to see all the internal changes in the device at each step
  - Can execute instructions one step at time and check outputs such as voltage levels to monitor effects etc.

DSP – Tools

- Debugger
    - Has a user interface on PC to modify and control the execution on the chip
    - Contents of DSP processor memory is loaded into debugger interface
    - Loaded from either emulator or serial comms link to DSP
    - Used to display programme execution info in a useful format for the programmer
    - Advantage over emulators - allows user to operate in real time and designer to see performance of chip in operation

Project Design...