Digital Signal Processing

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DSP: A Special Type of Embedded Processor

A unique form of embedded processor is the digital signal processor (DSP).

A DSP has all the major characteristics of an embedded processor with CPU, memory, and I/O on one chip.

Most DSPs use Harvard architecture with separate program and data memories.

DSPs execute a special type of program that is used to replace many forms of analog signal processing like filtering.

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What is DSP?

DSP is a technique where an analog signal to be processed is digitized by an analog-to-digital converter (ADC) then stored in the RAM of a DSP. The program implements an algorithm that emulates some analog processing technique such as filtering or modulation.

The processed data is stored in RAM then outputted to a digital-to-analog converter (DAC) to produce an analog output that is equivalent to that produced by analog processing circuits.

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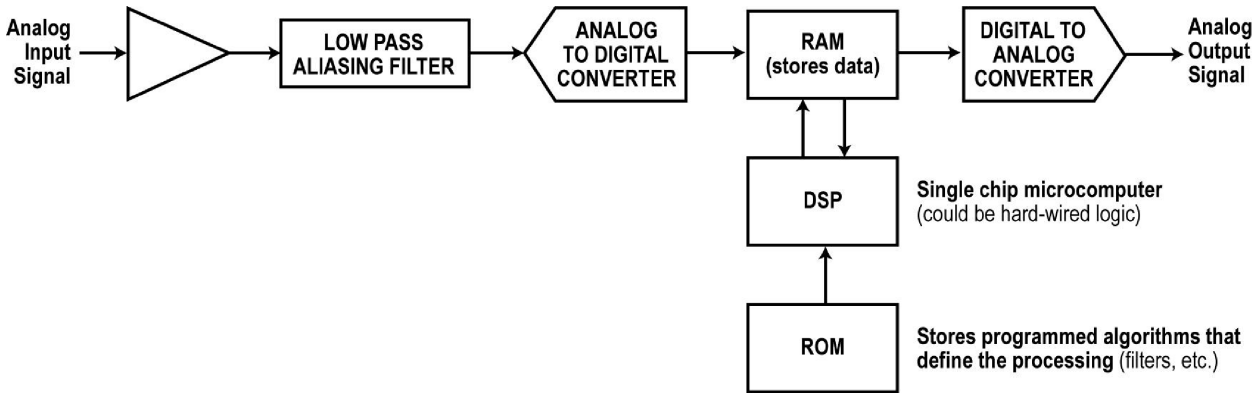
The DSP Concept



The figure shows a general block diagram of a DSP system. The analog signal to be processed is amplified and put through a low pass filter that restricts its bandwidth to prevent aliasing in the analog-to-digital converter (ADC).

The ADC samples the analog signal at a rate at least twice the highest frequency content. The binary number samples are usually stored in a random access (read/write) memory (RAM).

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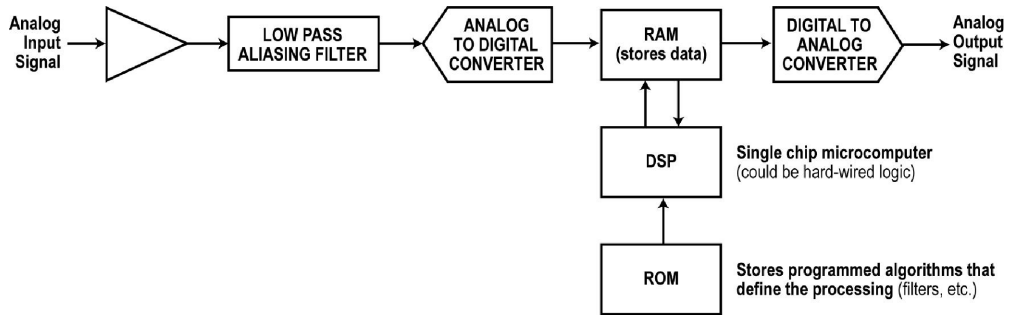
Digital Processing



These samples become the input data for a special integrated circuit (IC) microcomputer known as a digital signal processor (DSP). The DSP reads the data samples and processes them according to one or more algorithms programmed into the read-only memory (ROM). Each algorithm performs some basic processing technique such as filtering.

The processed data is then stored in RAM. It is next outputted to a digital-to-analog converter (DAC) that converts the data back into analog form. The output signal is one that you would expect to get from a comparable analog processing circuit.

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Why DSP?

Even though digital signal processing is more complicated and requires an expensive, special digital computer, there are four main reasons why it is replacing traditional analog processing techniques.

1. Compatibility with the already mostly digital world. Examples include filtering or otherwise processing digital music on a CD or an MP3 player and voice on a cell phone.
2. Ability to achieve processing results that are an improvement over analog techniques. For example, filters with superior selectivity (steep output transitions or skirts) over analog filters.
3. Ability to perform processing that cannot be easily done in analog form or done at all in analog form. One example is spectrum analysis to view frequency domain.
4. Because it is possible. Low cost DSP and other chips make DSP not only affordable but often lower in cost than some analog processing circuits.

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Common DSP Processes

These are the most commonly performed signal processing functions implemented in DSP. These occur in just about every electronic application.

Filtering (low pass, high pass, band pass, and notch).

Pre-emphasis and de-emphasis

Equalization

Encoding and decoding

Compression and decompression

Spectrum analysis

Modulation and demodulation

Mixing

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DSP Features: MAC

DSPs have some unique features not found on conventional embedded processors. These include Harvard architecture, single clock execution of instructions, multiply-accumulate instruction, shifters, and special addressing modes

The main feature is a special instruction that combines both multiplication and addition. These instructions are referred to as multiply and accumulate (MAC) instructions or multiply-add computing.

Most DSP algorithms are long sequences of repeated multiply and add instructions. To speed up processing, DSPs implement the MAC function with hardware so that a single clock cycle instruction can be used.

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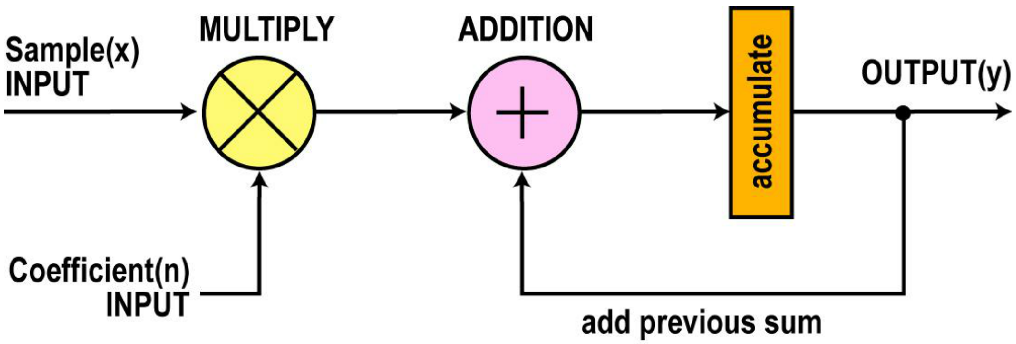
Block Diagram



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The basic format for most DSP calculations is:

$$Y = ax1 + bx2 + cx3 + dx4 + ex5 + fx6 + ...$$

The x values are the sequential samples of the analog input.

The variables labelled a, b, c, ...n are coefficients.

The figure above shows the block diagram of MAC function as implemented in software in the DSP.

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DSP Features: Shifter

Another unique architectural hardware feature is a set of shifters. These are registers that are usually 32-bits or more long that can shift right or left with logical or arithmetic shifts.

These are sometimes called barrel shifters.

Shifters are used to scale values and perform other operations unique to DSP algorithms.

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DSP Options

Any embedded controller or microprocessor can be programmed to do DSP operations but are slow compared to the special DSPs.

Programmable DSPs are optimized and the most flexible.

Hardwired DSP logic in an ASIC or PLD is used in some applications.

FPGAs are popular for fast DSP operations.

Some standard embedded controllers (ARM, MIPS, PIC) have been enhanced to do some DSP operations such as MAC instructions.

The manufacturers of programmable DSPs are Texas Instruments, Analog Devices, and Freescale (formerly Motorola)

Texas Instruments holds about 70 % market share with their TMS320xxxx chips.

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