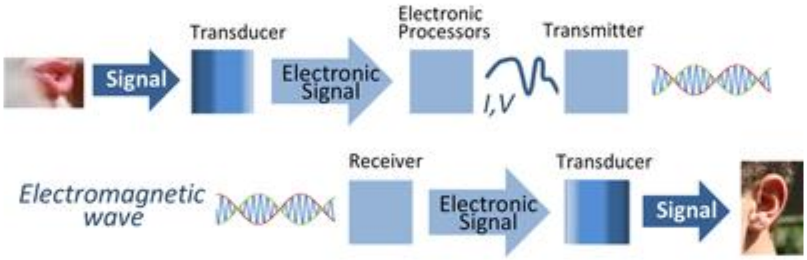
Signal processing



Signal transmission using electronic signal processing. Transducers convert signals from other physical waveforms to electric current or voltage waveforms, which then are processed, transmitted as electromagnetic waves, received and converted by another transducer to final form.

Signal processing is a subfield of mathematics, information and electrical engineering that concerns the analysis, synthesis, and modification of signals, which are broadly defined as functions conveying "information about the behavior or attributes of some phenomenon", such as sound, images, and biological measurements. Two different categories of signal process exist:

- **Analog signal processing** is for signals that have not been digitized, as in legacy radio, telephone, radar, and television systems. Analog signal processing is a type of signal processing conducted on continuous analog signals by some analog means. "Analog" indicates something that is mathematically represented as a set of continuous values. Analog values are typically represented as a voltage, electric current, or electric charge around components in the electronic devices. An error or noise affecting such physical quantities will result in a corresponding error in the signals represented by such physical quantities. Examples of *analog signal processing* include crossover filters in loudspeakers, "bass", "treble" and "volume" controls on stereos, and "tint" controls on TVs. Common analog processing elements include capacitors, resistors and inductors (as the passive elements) and transistors. Two different domains exist for the signal. On one side, the time domain that shows the amplitude of the signal with respect to time. On the other side, the Frequency domain, where the plot shows either the phase shift or magnitude of a signal at each frequency that it exists at. These can be found by taking the Fourier transform of a time signal and are plotted similarly to a bode plot. While any signal can be used in analog signal processing, only some types of signals that are used very frequently: Sinusoids, Impulse, Step
- **Digital signal processing** is the processing of digitized discrete-time sampled signals to perform a wide variety of signal processing operations. The signals processed in this manner are a sequence of numbers that represent samples of a continuous variable in a domain such as time, space, or frequency. It. Processing is done by general-purpose computers or by digital circuits such as ASICs, field-programmable gate arrays or specialized digital signal processors (DSP chips). Typical arithmetical operations include fixed-point and floating-point, real-valued and complex-valued, multiplication and

addition. Other typical operations supported by the hardware are circular buffers and lookup tables. Examples of algorithms are the Fast Fourier transform (FFT), finite impulse response (FIR) filter, Infinite impulse response (IIR) filter, and adaptive filters such as the Wiener and Kalman filters. DSP can involve linear or nonlinear operations. Nonlinear signal processing is closely related to nonlinear system identification and can be implemented in the time, frequency, and spatio-temporal domains.

A digital signal processor (DSP) is a specialized microprocessor (or a SIP block), with its architecture optimized for the operational needs of digital signal processing.

The goal of digital DSP signal processors is usually to measure, filter or compress continuous real-world analog signals. Most general-purpose microprocessors can also execute digital signal processing algorithms successfully, but dedicated DSPs usually have better power efficiency thus they are more suitable in portable devices such as mobile phones because of power consumption constraints. DSPs often use special memory architectures that are able to fetch multiple data or instructions at the same time.

The application of digital computation to signal processing allows for many advantages over analog processing in many applications, such as error detection and correction in transmission as well as data compression. DSP is applicable to both streaming data and static (stored) data.

History

According to Alan V. Oppenheim and Ronald W. Schafer, the principles of signal processing can be found in the classical numerical analysis techniques of the 17th century. Oppenheim and Schafer further state that the digital refinement of these techniques can be found in the digital control systems of the 1940s and 1950s.

Up until the end of the 1970s, signal processing was achieved, in large part, by using analogic technologies. The appearance of the first DSPs in approximately 1979 provoked a discontinuity in the technology of signal processing, shifting all analogic systems towards digital systems.

The main problems that arise with signal processing systems based on analogic electronics are their low versatility and limited capacity for processing complex algorithms. Versatility depends on the programming possibilities of the device. In spite of the fact that analogic processing systems can incorporate the characteristic of programmability, they are not comparable to what a DSP, designed specifically for signal processing, can offer. In fact, a DSP enables the programming of any algorithm that will determine the desired signal treatment. The DSPs are essentially high speed microprocessors designed to develop signal processing algorithms with elevated calculations.

In a DSP, the limitation at the time of executing an algorithm for signal processing is its velocity. Digital procedures are found to be disadvantageous in applications where great speed is required. Therefore, it is essential to realize them by using analogic techniques. It is important to point out that, due to technological improvements and the optimization of informal structures, the speed of DSPs has been increasing dramatically in recent years. Nonetheless, analogic signal processing is not likely to disappear. Currently a gradual transition in signal processing technologies is taking place. It is necessary to consider that the first DSPs were quite slow and although they solved the problem of complicated assembly, when the demand for greater velocity increased, it was necessary to turn to analogic technology.

Application fields of signal processing

- Audio signal processing – for electrical signals representing sound, such as speech or music
- Digital signal processing
- Speech signal processing – for processing and interpreting spoken words
- Image processing – in digital cameras, computers and various imaging systems
- Video processing – for interpreting moving pictures
- Wireless communication – waveform generations, demodulation, filtering, equalization
- Control systems
- Array processing – for processing signals from arrays of sensors
- Process control – a variety of signals are used, including the industry standard 4-20 mA current loop
- Seismology
- Financial signal processing – analyzing financial data using signal processing techniques, especially for prediction purposes.
- Feature extraction, such as image understanding and speech recognition.
- Quality improvement, such as noise reduction, image enhancement, and echo cancellation.
- Source coding, including audio compression, image compression, and video compression.
- Genomics, Genomic signal processing
- Applications of analog and digital signal processing

In this context, DSPs and all semiconductor devices are the foundation of microelectronic technologies and the support of the entire technological system of information and communication technologies (ICTs). This system includes all techniques that are related to the generating, transmission, reception, storage and processing of information, as much for human communication as for that among machines. The spectrum of technologies that embraces this definition is extensive as it includes very concrete applications (automatic, robotic, artificial intelligence) that can be used in different environments as well as support technologies (microelectronic, optoelectronic). Therefore, ICTs can be characterized as a technological system whose modules constitute a chain in which each link uses, out of necessity, the previous one until the final applications are realized.

TABLE 2. Semicondutor devices and components

Digital	Logic	Field-programmable gate arrays Mask-programmable gate arrays Standard-cell ASICs Full-custom ASICs	
		General-purpose circuits	Microprocessors Microcontrollers **Digital signal processors** Others
	Memory	RAMs	Dynamic RAMs Static RAMs Non-volatile RAMs Specialized
		ROMs	Mask-programmable Field-programmable
Analog	Sensors and transducers: sound, light, pressure, others Amplifiers, mixers, filters, RF circuits Opto-electronics: transmitters, receivers Power electronics Conversion circuits: analog-to-digital, digital-to-analog		

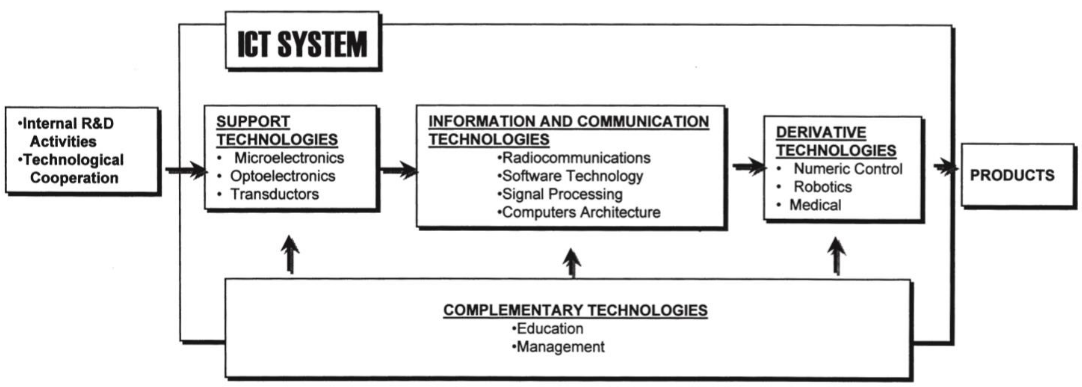


Fig. 7. Information and communication technologies system.

DSPs are the base of this technological chain and fulfill the task of supporting the functional development of ICTs. The technologies that are incorporated into the DSPs have no utility themselves if they are not applied in their natural area of incidence.

In addition, DSPs using digital techniques have made processing possible in real time of signals of elevated width band and have provoked a clear breaking-off with the analogic technologies used to date. It has been confirmed that the revolution that these devices have provoked can be compared to the one that the first microcomputers caused in the 1970s.

Applications of DSP include audio signal processing, audio compression, digital image processing, video compression, speech processing, speech recognition, digital communications, digital synthesizers, radar, sonar, financial signal processing, seismology and biomedicine. Specific examples include speech coding and transmission in digital mobile phones, room correction of sound in hi-fi and sound reinforcement applications, weather forecasting, economic forecasting, seismic data processing, analysis and control of industrial processes, medical imaging such as CAT scans and MRI, MP3 compression, computer graphics, image manipulation, audio crossovers and equalization, and audio effects units. Audio signal processing – for electrical signals representing sound, such as speech or music.

Characteristics

As with all complex mechanisms, DSPs have numerous characteristics that can be used as technology performance indicators: longitude of data with which it can work, internal memory, capacity to direct memory, etc. In the table we can see the main technical characteristics of a sample of 29 DSPs that were introduced into the marketplace between 1976 and 1995. The efficiency parameter can be obtained by dividing the data type with which the DSP can work and its cycle time. The results are standardized with respect to the information received for ADSP21060.

TABLE 3. Main characteristics of a sample of 29 DSPs

Year	Model	Family	Manufacturer	Data type	Cycle time (ns)	Efficiency
1978	S2811	Fixed	AMI	12	300	1.0037E-36
1980	uPD7720	Fixed	NEC	16	250	1.9275E-35
1982	TMS32010	Fixed	Texas Instruments	16	390	1.2356E-35
1982	HD61810	Fixed	Hitachi	12	250	1.2047E-36
1983	MB8764	Fixed	Fujitsu	16	100	4.8188E-35
1983	6386	Fixed	Toshiba	16	250	1.9275E-35
1985	TMS32020	Fixed	Texas Instruments	16	195	2.4765E-35
1985	uPD77220	Fixed	NEC	24	100	1.2353E-32
1985	WEDSP32	Floating	ATT	24E8	160	0.1562
1986	ADSP2100	Fixed	Analog Devices	16	125	3.8551E-35
1986	LM32900	Fixed	National	16	100	4.8188E-35
1986	uPD77230	Floating	NEC	24E8	150	0.166
1987	TMS320C25	Fixed	Texas Instruments	16	100	4.8188E-35
1987	DSP56000	Fixed	Motorola	24	74	1.6671E-32
1987	MB86232	Floating	Fujitsu	24E8	150	0.166
1988	DSP16	Fixed	ATT	16	55	8.7617E-35
1988	ADS2101A	Fixed	Analog Devices	16	80	6.0235E-35
1988	WEDSP32C	Floating	ATT	24E8	80	0.312
1988	TMS320C30	Floating	Texas Instruments	24E8	50	0.5
1990	TMS320C50	Fixed	Texas Instruments	16	50	9.6375E-35
1990	ADSP21010	Floating	Analog Devices	24E8	50	0.5
1992	ADSP21020	Floating	Analog Devices	24E8	30	0.833
1992	DSP32C	Floating	ATT	24E8	50	0.5
1993	TMS32C50	Fixed	Texas Instruments	16	40	1.2047E-34
1993	TMS320C30	Floating	Texas Instruments	24E8	40	0.625
1994	DSP1610	Fixed	ATT	16	25	1.9275E-34
1994	TMS320C31	Floating	Texas Instruments	24E8	33	0.758
1994	ADSP21060	Floating	Analog Devices	24E8	25	1
1995	TMS320C5x	Fixed	Texas Instruments	16	25	1.9275E-34