Digital Signal Processing

By: Engr. Yogeswaran s/o Seleappan, Grad. IEM

DSP, or Digital Signal Processing, as the term suggests, is the processing of signals by digital means. A signal in this context can mean a number of different things. Historically, the origin of signal processing is in electrical engineering, and a signal here means an electrical signal carried by a wire or telephone line, or perhaps by a radio wave. Generally, however, a signal is a stream of information representing anything from stock prices to data from a remote-sensing satellite. The term 'digital' comes from 'digit', meaning a number, so 'digital' literally means numerical; the French word for digital is numerique. A digital signal consists of a stream of numbers, usually (but not necessarily) in binary form. The processing of a digital signal is done by performing numerical calculations.

ANALOG AND DIGITAL SIGNALS

In many cases, the signal of interest is initially in the form of an analog electrical voltage or current, produced for example by a microphone or some other type of transducer. In some situations, such as the output from the readout system of a CD (compact disc) player, the data is already in digital form. An analog signal must be converted into digital form before DSP techniques can be applied. An analog electrical voltage signal, for example, can be digitised using an electronic circuit called an analog-to-digital converter or ADC. This generates a digital output as a stream of binary numbers whose values represent the electrical voltage input to the device at each sampling instant.

ANALOG AND DIGITAL FILTERS

In signal processing, the function of a filter is to remove unwanted parts of the signal, such as random noise, or to extract useful parts of the signal, such as the components lying within a certain frequency range.

Figure 1 illustrates the block diagram of the basic idea.

Figure 1: Basic block diagram of a 'Filter'

There are two main kinds of filter, analog and digital. They are quite different in their physical makeup and in how they work.

An analog filter uses analog electronic circuits made up of components such as resistors, capacitors and op amps to produce the required filtering effect. Such filter circuits are widely used in applications such as noise reduction, video signal enhancement, graphic equalisers in hi-fi systems and many other areas.

There are well-established standard techniques for designing an analog filter circuit for a given requirement. At all stages, the signal being filtered is an electrical voltage or current which is the direct analogue of the physical quantity (e.g. a sound or video signal or transducer output) involved.

A digital filter uses a digital processor to perform numerical calculations on sampled values of the signal. The processor may be a general-purpose computer such as a PC, or a specialised Digital Signal Processor chip.

The analog input signal must first be sampled and digitised using an ADC. The resulting binary numbers, representing successive sampled values of the input signal, are transferred to the processor, which carries out numerical calculations on them. These calculations typically involve multiplying the input values by constants and adding the products together. If necessary, the results of these calculations, which now represent sampled values of the filtered signal, are output through a DAC (digital-to-analog converter) to convert the signal back to analog form.

Figure 2 shows the basic setup of such a system.

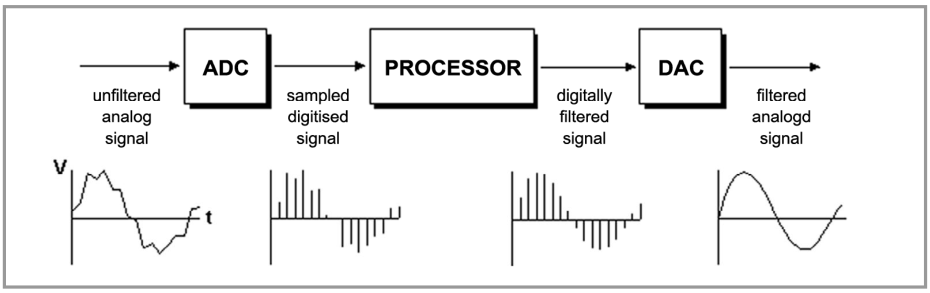

Figure 2: Diagram to illustrate the basic setup of signal processing with ADC and DAC systems

Note that in a digital filter, the signal is represented by a sequence of numbers, rather than a voltage or current.

SIGNAL PROCESSING

Signals commonly need to be processed in a variety of ways. For example, the output signal from a transducer may well be contaminated with unwanted electrical 'noise'. The electrodes attached to a patient's chest when an ECG is taken measure tiny electrical voltage changes due to the activity of the heart and other muscles. The signal is often strongly affected by 'mains pickup' due to electrical interference from the mains supply. Processing the signal using a filter circuit can remove or, at least, reduce the unwanted part of the signal. Increasingly, nowadays, the filtering of signals to improve signal quality or to extract important information is done by DSP techniques rather than by analog electronics.

DEVELOPMENT OF DSP

The development of digital signal processing dates from the 1960s with the use of mainframe digital computers for number-crunching applications such as the Fast Fourier Transform (FFT), which allows the frequency spectrum of a signal to be computed rapidly. These techniques were not widely used at that time, because suitable computing equipment was generally available only in universities and other scientific research institutions.

DIGITAL SIGNAL PROCESSORS

The introduction of the microprocessor in the late 1970s and early 1980s made it possible for DSP techniques to be used in a much wider range of applications. However, general-purpose microprocessors such as the Intel x86 family were not ideally suited to the numerically-intensive requirements of DSP. Thus, during the 1980s, the increasing importance of DSP led several major electronics manufacturers (such as Texas Instruments, Analog Devices and Motorola) to develop Digital Signal Processor chips – specialised microprocessors with architectures designed specifically for the types of operations required in digital signal processing.

(Note that the acronym DSP can variously mean Digital Signal Processing, the term used for a wide range of techniques for processing signals digitally, or Digital Signal Processor, a specialised type of microprocessor chip).

Like a general-purpose microprocessor, a DSP is a programmable device, with its own native instruction code. DSP chips are capable of carrying out millions of floating point operations per second, and like their better-known general-purpose cousins, faster and more powerful versions are continually being introduced. DSPs can also be embedded within complex 'system-on-chip' devices, often containing both analog and digital circuitry.

APPLICATIONS OF DSP

Nowadays, DSP technology is commonplace in devices such as mobile phones, multimedia computers, video recorders, CD players, hard disc drive controllers and modems, and will soon replace analog circuitry in TV sets and telephones. An important application of DSP is in signal compression and decompression. Signal compression is used in digital cellular phones to allow a greater number of calls to be handled simultaneously within each local 'cell'. DSP signal compression technology allows people not only to talk to one another but also to see one another on their computer screens, using small video cameras mounted on the computer monitors, with only a conventional telephone line linking them together. In audio CD systems, DSP technology is used to perform complex error detection and correction on the raw data as it is read from a CD.

Although some of the mathematical theory underlying DSP techniques, such as Fourier and Hilbert Transforms, digital filter design and signal compression can be fairly complex, the numerical operations required to actually implement these techniques are very simple, consisting mainly of operations that could be done on a cheap four-function calculator. The architecture of a DSP chip is designed to carry out such operations incredibly fast, processing hundreds of millions of samples every second, to provide real-time performance: that is, the ability to process a signal 'live' as it is sampled and then output the processed signal, for example, to a loudspeaker or video display. All of the practical examples of DSP applications mentioned earlier, such as hard disc drives and mobile phones, demand real-time operation.

The major electronics manufacturers have invested heavily in DSP technology. As they now find application in mass-market products, DSP chips account for a substantial proportion of the world's market for electronic devices. Sales amount to billions of dollars annually, and seem likely to continue to increase rapidly. ■

REFERENCES

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