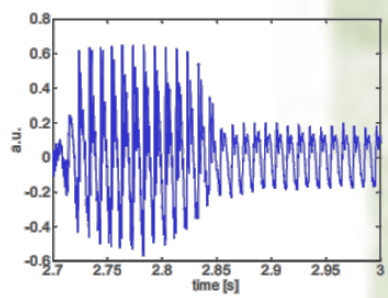
Applications of digital signal processing in Medicine

Digital signal processing is one of the main tools in modern technology since it relies on the fast developing digital integrated circuit technology, which in turn allows for high performance computing machines at relatively low cost. These will be illustrated with examples from medical applications, where signal analysis has been widely applied in patient monitoring, diagnosis and prognosis, as well as physiological investigation and in some therapeutic settings (e.g. muscle and sensory stimulation, hearing aids).

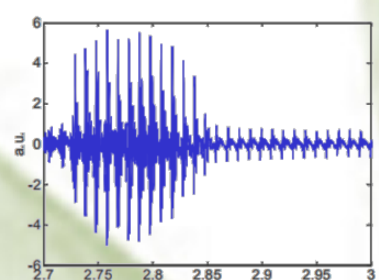
Example-1

Hearing aid

A hearing aid may be used to illustrate the operation of a DSPS: the sound is picked up by the microphone, converted into an electric signal, and then digitized. The digital signal is then filtered to selectively amplify those frequency bands in which the patient shows the most severe hearing loss. Further processes may also be applied, including amplitude compression, in which the system gain is reduced when the amplitude exceeds some pre-defined threshold values, in order to avoid excessive loudness to the ear. Finally the processed digital signal is converted back to analog form in the digital-to-analog (D/A) converter, and delivered to the ear via the earphone.



igure 2. A short segment of speech signal, that may form the input to a hearing aid. Th segment displayed corresponds to the sound /um/.



EXAMPLE 2. The acquisition of a blood pressure signal.

A blood pressure (BP) signal contains clinically relevant components up to about 20 Hz. In the current example it is also known that the signal is contaminated by noise at the mains frequency (50Hz) and other noise (mainly below 50 Hz) may also be present. What is the minimum sampling rate required? The sampling rate has to be above 100Hz, as the highest frequency present is 50 Hz. It is the maximum frequency present in the signal, not the maximum frequency of interest, which determines the minimum sampling rate required. If a sampling rate below 100 Hz is employed, the mains (and other) noise may be aliased into the clinically relevant frequency band of BP signal and could contaminate the BP signal (see figure below). If the noise (mains I nterference) is removed prior to sampling, by a low-pass (anti-alias) filter with a cut-off frequency at say 20 Hz, the sampling rate could be reduced to a value above 40 Hz, without significant aliasing occurring. This was carried out below, and a sampling rate of 67 Hz was chosen.

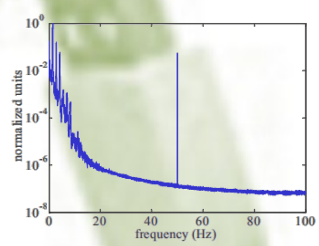


Figure 9. The power spectrum of this signal shows that most of the power is concentrated in frequencies below approximately 20 Hz, with peaks at the heart-rate (about 1.4 Hz) and multiples of this frequency (the harmonics). In addition there is a sharp peak at mains frequency (50Hz).

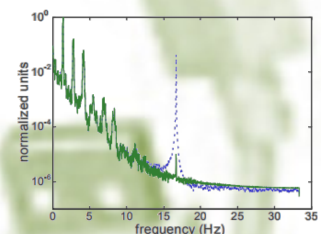


Figure 10. The power spectrum of this signal, sampled at 67 Hz. Without the anti-alias filter (dotted lines), the 50 Hz noise is aliased, and appears as a very large peak at 17 Hz (67-50 Hz). With the anti-alias filter (solid line), this peak is very much reduced (though not eliminated, due to the imperfection of the filter), and can be considered insignificant.

Reference: Digital Signal Processing with Applications in MedicinePaulo S. R. Diniz***, David M. Simpson**, A. De Stefano**, and Ronaldo C. Gis-mondi*.

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Arear of Interest: **Image Processing,, Digital Signal Processing, Embedded Systems and Robotics**