Digital methods for sinusoidal signal synthesis

A computer-based digital function generator can generate any arbitrary type of signal in the frequency range from 0 Hz to 20,000 Hz, SNR = 95 dB, and with no harmonic or intermodulation distortion (when based on 16-bit, 44.1kHz-sampling rate D/A converter). Frequency stability is determined by a quartz clock in the D/A converter which has an accuracy in the order of 1/10^7. Generation of sinusoidal waves is of primary importance in digital synthesis, since due to the Fourier theorem any periodic wave may be constructed via additive synthesis (an addition of pure tones with appropriate amplitudes and phases). There are many alternative methods to digitally generate pure tones [1,2,3,7]. Very often real-time synthesis is accomplished by using a sine function look-up table [2,7]. A limitation to this approach is the short length of the sine table (N). In order to synthesise any arbitrary frequency using the look-up table method, one must synthesize the values of the sine function using an interpolation process [2]. Interpolation between sine samples leads to the generation of harmonic and intermodulation distortion by this algorithm [2,7]. Another problem is that synthesis of more complex signal (combinations of several sinusoids with certain amplitudes and phases) in real-time could put too much performance demand on the computer's DSP chip or microprocessor.

Digital Function Generator software for the NeXT computer

A new high precision digital synthesis method has been developed for the generation of the high-quality audio signals [7]. This method has been successfully implemented on the NeXT computer and was used with great success in teaching of acoustics, psychoacoustics, electronics and in various research projects. During the course of this research, a software package called Digital Function Generator (DFG) was written. At the present the DFG software consists of 5 modules. The Principles of Digital Audio module (Fig.1) allows synthesis of pure tones and white noise. It can also be used to illustrate concepts of signal amplitude, frequency, phase, interference, coherence, incoherence, signal ramping, additive synthesis, beats, virtual pitch as well as to demonstrate quantization, dithering, aliasing / hard clipping / harmonic / intermodulation distortions, etc. The Modulation (AM, FM & AMF) module allows synthesis of pure tones which can be Amplitude Modulated (AM), Frequency Modulated (FM) or Amplitude and Frequency Modulated (AFM). The Additive Synthesis module allows very flexible synthesis of complex sounds from their Fourier components. The Sweep Generator (AS, FS & APS) module is a very flexible tool for generating arbitrary amplitude (AS), frequency (FS) or amplitude and frequency (APS) sweeps. The Function Generator module (Fig.2) can be used to synthesize sine, square, triangular, sawtooth, pulse and white noise signals.

RAM-based method for sinusoidal signal synthesis

In order to generate sinusoidal signal in this method, one has to synthesize audio file, which contains appropriate samples in RAM (Random Access Memory) or on the Hard or Optical Disk. Then reading of this file in real time to the D/A converter is performed to generate the desired audio signal [6]. However there is a limit on the duration of this signal due to memory consumption = 88,200 Bytes/sec (for 16-bit, 44.1 kHz D/A converter). In many situations long durations of test signal are required. In this case the most appropriate way to generate sine wave is to construct the audio file in RAM in such a way as to be able to read this file to the D/A converter over and over again (looping) [7].

Generation of frequencies 1Hz, 2Hz, 3Hz.....20,000Hz with the NeXT computer

NeXT computer has a 16-bit, 44.1 kHz stereo set of the D/A converters (CD quality), available 16-bit, 44.1 kHz stereo set of the A/D converters, built in DSP processor (Motorola 56001), from 8 to 256 MBytes of RAM and from 100 MBytes to 5.6 GBytes of internal hard disk storage. This, therefore, is the best computer for digital audio and acoustical applications available today. With RAM buffer size N=44,100 (176,400 Bytes - which is small by the NeXT standards) the available frequencies for looping are: 1 Hz, 2 Hz, 3 Hz, ......20,000 Hz. It takes about 3 sec for Motorola 68040-based NeXT machine to generate a pure tone soundfile of this length. Once generated, this file can be played in loop from RAM indefinitely.

Figure 1. 1000 Hz pure tone generated with the Digital Function Generator (Principles of Digital Audio module) and displayed with the Spectrum Analyzer.
arbitrary audio signals was successfully implemented on the NeXT computer. Since NeXT is a multitasking, UNIX operating system-based machine, many software applications can run on it simultaneously. DFG software by-design puts very little demand on the hardware and does not use the built-in Motorola DSP 56001 processor for sound synthesis. This allows running of the Digital Oscilloscope (Fig. 2), Spectrum Analyzer (Fig. 1) and Sound Recording software simultaneously with DFG. This in turn allows very sophisticated tests and demonstrations in such fields as acoustics, electronics, physics and engineering to be performed on a single NeXT computer.

References: