Digital Function Generator for NeXT
Demo Version 2.0

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General Information

The **Digital Function Generator (DFG)** software has been developed under NeXT Release 2.0 by Digital Recordings, Halifax, Nova Scotia, Canada.

The **DFG/NeXT** combination is a powerful tool for generating arbitrary sounds of arbitrary complexity and ultimate quality. Since DFG does not use DSP resources (Motorola 56001 chip), it can run simultaneously with such applications as the Digital Oscilloscope and Spectrum Analyzer (both applications come with NeXT). Therefore, the single DFG/NeXT combination can be used to perform sophisticated tests and experiments, since it can synthesize and analyze signals at the same time. The DFG is an ideal signal source for many applications in the field of acoustics, psychoacoustics, physics, architecture, audiology, electronics, electroacoustics, vibration measurements and transducer testing.

Software Specifications / Parameters

Stereo output - different waveforms can be synthesized in two independent channels.

Frequency range from 0 to 20,000 Hz.

Frequency stability +/- 0.0001 Hz (accuracy of the quartz clock).

Amplitude adjustable continuously from -140 to 0 dB or from 0 to 32,767.

Phase adjustable continuously from 0 to 360 degrees.

S/N ratio = 95 dB (with dither).

No harmonic and no intermodulation distortion.

DFG does not use DSP resources (Motorola DSP 56001 processor), therefore the DFG, Digital Oscilloscope and Spectrum Analyzer can run simultaneously.

The simultaneous playback of sound by DFG and the recording of this sound via microphone input or the stereo A/D interface (from Singular Solutions, Ariel or MetaResearch**)** allows for very flexible testing and experimental procedures.

Generated sounds are written to standard stereo, linear 16-bit soundfiles (*.snd). These files can be used in other sound applications such as sound editors. Complex sounds can be saved for fast retrieval and playback.

Available Signals: sine wave, square wave, triangular wave, sawtooth wave, pulse, white noise, AM, FM and AFM modulation, frequency sweep, amplitude sweep, amplitude plus frequency sweep, additive synthesis, etc.

DFG Modules

The Digital Function Generator software consists of five modules:

Principles of Digital Audio - for generating pure tones and white noise, 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.

Modulation (AM, FM, AFM) - for generating amplitude modulated tones (AM), frequency modulated tones (FM) and amplitude plus frequency modulated tones (AFM).

Additive Synthesis - for generating complex sounds synthesized from their Fourier components.

Sweep Generator (AS, FS & AFS) - for generating linear, logarithmic, up or down types of amplitude sweeps (AS), frequency sweeps (FS) and amplitude plus frequency sweeps (AFS).

Function Generator - for generating waves such as sine, square, triangular, sawtooth, pulse and to generate white noise.

Demo Version 2.0

The Demo Version 2.0 demonstrates the Principles of the Digital Audio module. It has the same functionality with the following restrictions imposed on some of the variables:

Frequency can be set only between 200 and 2,000 Hz
Duration can be set only between 22,050 and 88,200 samples (0.5 to 2 sec)
Number of loops cannot exceed 600.

Use of DFG in Teaching and Research

In the past year the DFG/NeXT combination has been used successfully at Dalhousie University, Halifax, Nova Scotia, Canada and at the Technical University of Gdansk, Gdansk, Poland, in various research and students projects and in the teaching of various courses related to acoustics, psychoacoustics, hearing aids, instrumentation, electronics, audiology and speech pathology.

In particular, the Principles of Digital Audio module, illustrated by this demo, has been used to generate pure tones and white noise, to illustrate concepts of signal amplitude, frequency, phase, interference, coherence, incoherence, signal ramping, beats and virtual pitch. Also, it has been used to demonstrate quantization, dithering, aliasing / hard clipping / harmonic/ intermodulation distortions, etc.

Students generated signals according to parameters input through the Graphical User Interface and listened to these signals via headphones or an amplifier with a set of speakers. The A/D64x Interface from Singular Solutions was used to input the generated signal back to the NeXT computer, so the signal could then be displayed on the Oscilloscope and Spectrum Analyzer. The same interface was used to digitally transfer generated test signals to a DAT (Digital Audio Tape) recorder. These recordings were used in various experiments conducted in electronic and acoustical labs.

The quality of signals generated with DFG is higher than the quality of signals available on most test CDs. Also, DFG can generate a much wider variety of test signals than are available on CDs. This proved to be very helpful in both teaching and research.

Teachers' and students' satisfaction with DFG has been very high. Concepts which have often been difficult or even impossible to demonstrate with standard equipment, can now be easily demonstrated, both acoustically and visually, with the DFG/NeXT/A/D64x combination. This dramatically increased the speed of learning and the level of understanding.

Installation Instructions

- Create subdirectory **DFG_Sounds** under your work directory.
- Copy **DFG_demo** and **DFG_README.wn** files to the directory of choice (eg. DFG_Sounds).
- Read **DFG_README.wn** file for further information about DFG and how to use it.

How to Use DFG Program

Warning: Decrease Volume on NeXT Computer (or on external amplifier) to avoid damage to your speakers or your hearing !

DFG software is intuitive to use and was designed with ergonomics in mind. However, we recommend that you read the following instructions before using the software.

- To start the application, double click on DFG_demo icon.
- Press "Make" button. This will produce 1000Hz.snd file in DFG_Sounds subdirectory.
- Decrease volume on NeXT (or on external amplifier) and press "Play" button. This will play 1,000 Hz sound for 1 sec. Pressing "Loop" button will play 1,000 Hz sound for 60 sec.
- You can use the 1000Hz.snd file as a scratch file to produce any sounds. If you want to save the soundfile under a different name use any file name with an extension *.snd to indicate the content of the file to other programs (for example the sound editor, etc.)
- Change any parameters on the DFG screen and press "Make" button. It takes about 4 seconds to make a 1 sec long file on the 68040 machine. Frequently used signals can be stored in separate files. The "Play" and "Loop" buttons will play or loop any soundfile, as long as its name appears in the text window. When entering data in the "Pure Tone Parameters" box or the "Dither / Noise Parameters" box, it is recommended that the "Return " key is pressed after each data entry. This will not only edit the entered value but it will also select text in the next text field speeding up the data entry process.
- More than one DFG panel can be opened at once. One panel can play one soundfile, while the other is synthesizing a new soundfile (different file names must be used in this case). Parameters can be changed (including the file name) during playback of sound and the same panel can be used for simultaneous synthesis of a new soundfile (while playing another soundfile). This is useful during demonstrations and saves time.

Variables and Buttons Used in the Software

The following is a short description of variables and buttons used in the software :

The **Mono / Stereo** switch allows a mono or stereo signal to be synthesized. In mono position, Left and Right channels are added together (pure tones and noise) to allow various demonstrations such as: interference, additive synthesis, monaural beats, intermodulation distortion, addition of coherent and incoherent noise, etc.

Amplitude (pure Tone) is any real number from 0 to 32,767 (or from -140 dB to 0 dB) and represents the amplitude of the signal. Values above 32,767 are allowed for demonstration of clipping distortions. Maximum recommended value of amplitude is 30,000. Above this value harmonic distortion on the output is observed due most probably to nonlinear response of analog output of NeXT computer. Quantization step is equal to 1 for 16 bit resolution, 2 for 15 bit resolution, 4 for 14 bit resolution, etc.

Frequency is any real number from 0 to 22,050 and represents the frequency of the signal in Hz. Values above 22,050 are allowed for demonstration of aliasing distortion. In the Demo Version 2.0 frequency can be set only between 200 and 2,000 Hz. Avoid loud levels when listening through the built-in speaker, since it can cause damage to it. Practical range for this speaker is from 100 Hz to 15,000 Hz. For best results use headphones or an external amplifier and speakers.

Phase is any real number from 0 to 360 and represents the phase of the signal in degrees. There is a small time delay between channels in the NeXT computer. The DFG program will allow you to measure this time difference on your machine and compensate for it if needed. The reason for this time delay is probably the analog reconstruction filter.

Dither is a small additive noise used to eliminate the harmonic and intermodulation distortion generated in typical generators. It also allows one to eliminate so-called "digital deafness" and in turn to record and generate sounds at levels below the quantization step. With dither the amplitude of a 1,000 Hz tone can be set to 0.01 and seen on the display with 2,048 points FFT (using for example the sound editor program "edsnd"). This is 130 dB below the maximum amplitude level ! In DFG the standard NeXT function random() is used to generate white random noise with uniform PDF (Probability Density Function). Dither (or noise) is coherent or incoherent between L and R channels, depending on the switch position on the panel. Optimal [-0.5;+0.5] dither is generated when its amplitude is set to 0.5. For larger values more noise is generated. When the pure tone amplitude is set to 0 and the noise amplitude adjusted to an arbitrary

value, a white noise with uniform PDF can be generated. When adding noise and pure tone together, it should be remembered that : (pure tone amplitude)+(noise amplitude) should be =< 32,767 to avoid hard clipping distortion. Dither/Noise amplitude is multiplied by 1 for 16 bit resolution, by 2 for 15 bit resolution, by 4 for 14 bit resolution, etc. Therefore when dither/noise amplitude is set to 0.5 it is adjusted properly when quantization is changed (it would be 0.5 for 16 bit resolution, 1 for 15 bit resolution, 2 for 14 bit resolution, etc. - or a half quantization step).

The **Coherent / Incoherent** switch allows coherent or incoherent noise signal to be synthesized. In the coherent position, noise in the Left and the Right channels is identical. The only difference could be its amplitude, which is adjusted by amplitude sliders.

Amplitude (noise) is any real number from 0 to 32,767 (or from -140 dB to 0 dB) and represents the amplitude of the noise. Values above 32,767 are allowed for demonstration of clipping distortions. Maximum recommended value of amplitude is 30,000. Above this value harmonic distortion on the output is observed, probably due to the nonlinear response of analog output of the NeXT computer. Noise amplitude is expressed in quantization steps. One quantization step is equal to 1 for 16 bit resolution, 2 for 15 bit resolution, 4 for 14 bit resolution, etc. This means, that noise with an amplitude = 25 for 14 bit resolution has an absolute amplitude value of 24*4=100.

Seed allows a choice of different noise sequences. When the same seed number is used, the same noise sequence is generated. Please see NeXT manuals for additional explanations about srandom() and random() functions.

Quantization allows adjustment of the number of bits used in the D/A conversion. A quantization step is equal to 1 for 16 bit resolution, 2 for 15 bit resolution, 4 for 14 bit resolution, etc. Quantization levels are at ....,-2,-1,0,+1,+2,.... for 16 bit, and at ....,-4,-2,0,+2,+4,..... for 15 bits etc.

Linear Amplitude Ramping creates linear fade-in and linear fade-out of the sound within a chosen time. Ramping is only applied to pure tone signals. It is not applied to noise.

The **Duration** of a signal is expressed in the number of samples or seconds. If duration in seconds is chosen, "Return" should be pressed to translate it to number of sampling points (which is used by the program). Any number in the range of 0 to 60 seconds can be chosen. Total playback length = (duration) * (number of loops).

The **Make button** creates a soundfile with chosen parameters. The name of the soundfile and the path can be modified in the text window. If there is no need to save a file, the same name can be used again. Each time the "Make" button is pressed, the file whose name appears in the text window is overwritten. The *.snd extension should be used when making soundfiles. Since they are standard format soundfiles, they can be used in other sound playback programs and sound editors. If the name of an already existing *.snd file is entered, it can be played with either the "Play" or "Loop" button.

The **Loop button** plays a *.snd file the number of times indicated in the text window. Total playback time = duration * number of loops. This button can be used to play "in loop" any soundfile, as long as its name appears in the text window. For duration 44,100, frequencies 1Hz, 2Hz, 3Hz, ... , 20,000Hz can be played in loop without a click (seem-less). For duration 441,000, frequencies 0.1Hz, 0.2Hz, 0.3Hz, ... , 20,000Hz can be played in loop without a click.

The **Stop button** stops looping or playback of a soundfile at any time.

The **Play button** starts playback of a soundfile. Soundfiles of any length can be played.

Your Satisfaction and your Suggestions

We hope that you will enjoy the DFG_demo. There are many creative ways to use this software in both teaching and research. All suggestions regarding the DFG software and its use will be greatly appreciated. This will help to improve this teaching and research tool in the future.

More Information

For more information about the DFG software and how to order it please contact :

Marek Roland-Mieszkowski, Ph.D.
Digital Recordings
5959 Spring Garden Rd., Suite 1103
Halifax, Nova Scotia, B3H - 1Y5
Canada

Tel. (902) 429-9622
E-mail: mmieszko@ac.dal.ca