Noise Generators & Subtractive Synthesis

Kreatives Programmieren 1

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Noise Generators & Subtractive Synthesis

>Subtractive synthesis creates musical tones out of complex sources by sculpting away selected portions of the spectrum of the source. In subtractive synthesis, a source with a broad spectrum, such as white noise or a narrow pulse, serves as the raw material out of which a musical tone is formed by filtering.

Noise generators

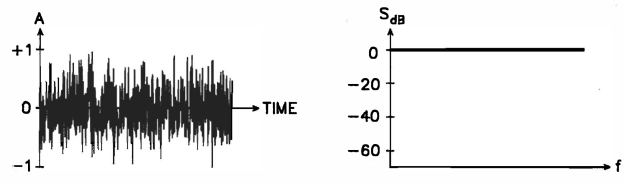


Figure: White Noise Distribuition

Oscillator vs Natural Sounds vs Noise

> An oscillator is designed to produce a periodic waveform with well-defined spectral components. The spectrum is a discrete spectrum; that is, the energy is found at specific, harmonically related frequencies. The opposite of a discrete spectrum is a distributed spectrum, in which energy exists everywhere within a range of frequencies. Most of the noise sounds found in nature have distributed spectra, and thus algorithms designed to generate distributed spectra are called noise generators.

Random Phenomena

> Certain phenomena have the characteristic that their repeated occurrence, even under the same set of conditions, will not always lead to the same result. Members of this class are called random phenomena. Even though the exact outcome cannot be predicted, they exhibit a certain amount of statistical regularity that can be used to describe them and to predict the probability of any given occurrence. The statistical characterization of a random signal is used to determine its frequency. In sound synthesis, randomness is used to generate distributed spectra. The waveform pictured above is a segment of the waveform of white noise. If it were digitized, there would be no recognizable pattern of sample values; in fact they would appear to be randomly distributed. The amplitude of the digitized white noise is characterized by a range - the interval within which the maximum and minimum sample values occur.

Random Phenomena

> In the figure, the range is - 1 to + 1 . Because, unlike a periodic waveform, a repeating pattern of samples cannot be identified, signals of this type are referred to as *aperiodic". White noise has a uniformly distributed spectrum. Between any two frequencies a fixed distance apart, there is a constant amount of noise power. For instance, there is the same amount of noise power in the band between 100 and 200 Hz, as there is between 7900 and 8000 Hz. White noise makes the "hissing"[ˆ Zischen] sound often associated with white noise generated by electronic means.

Spectral distribution

The actual spectral distribution S(f) at frequencyfis given by:

$$S_{(f)} = \frac{\sin(\frac{\pi * f}{f_s})}{\frac{\pi * f}{f_s}}$$

Spectral distribution in Common Lisp:

```
(defun Sdistri (f fs)
  (let*
      ((lst   (loop for i from 1 to f
                    collect (/ (sin (/ (* pi i) fs))  (/ (* pi i) fs) )))
       (min  (apply #'min lst))
       (max  (apply #'max lst))
       (diff (- max min)))
    (format nil "~% min: ~a ~% max: ~a ~% difference: ~a (~a dB)"
            min max diff (* 20 (log (- 1 diff) 10)))))

CL-USER> (Sdistri 22050 44100)
"
     min: 0.6366197723675814d0
     max: 0.9999999991541929d0
     difference: 0.3633802267866115d0 (-3.922397529063064d0 dB) "
```

Sample generation of noise

It deviates slightly from a uniform distribution because of a frequency bias inherent in the process of sample generation.

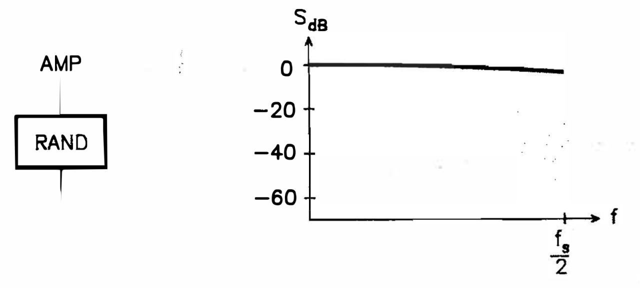


Figure: Digital White Noise Distribuition

Sound Source for Subtractive Synthesis

> Any sound can be used as a source for subtractive synthesis. Because the subtractive process alters the spectral balance of a sound, the technique has the greatest effect when applied to sources with rich spectra.(...) There are two kinds of spectrally rich signal generators that are commonly used as sources: noise white and pink and pulse generators (in MaxMSP: click~ in Csound: buzz[2]

[2] buzz and gbuzz are useful as complex sound sources in subtractive synthesis. buzz is a special case of the more general gbuzz in which klh = kmul = 1; it thus produces a set of knh equal-strength harmonic partials, beginning with the fundamental. (This is a band-limited pulse train; if the partials extend to the Nyquist, i.e. knh = int (sr / 2 / fundamental freq.), the result is a real pulse train of amplitude xamp.) [link].

White vs Pink Noise

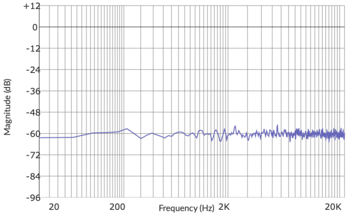


Figure: White Noise

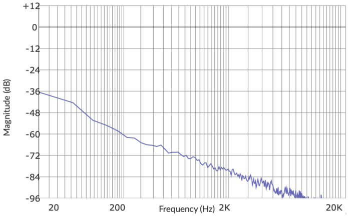


Figure: Pink Noise

Filters

> Filters change the characteristics of sounds by rejecting unwanted components in a signal or by otherwise shaping the spectrum. A filter modifies the amplitude and phase of each spectral component of a signal passing through it, but it does not alter the frequency of any signal or any component.

Low- and Highpass Filter

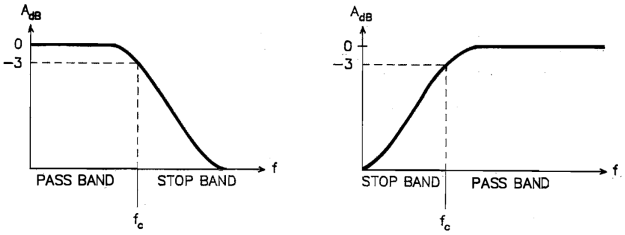


Figure: Lowpass and Highpass Filters

Bandpass Filter

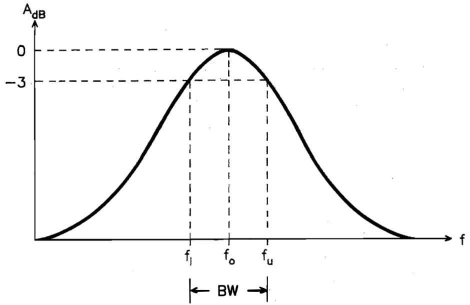


Figure: Bandpass Filter

- CF or fo: center frequency
- BW: bandwidth
- two cutoff frequencies: fu - upper frequency; fl - lower frequency

Bandpass Filter

The center frequency is the geometric average of the upper and lower cutoff frequencies:

$$f_0 = \sqrt{f_l * f_u}$$

The response of a bandpass filter is often described by terms such as sharp (narrow) or broad (wide), depending on the actual width. The passband sharpness is often quantified by means of a quality factor Q. When the cutofff requencies are defined at the -3-dB points, Q is given by:

$$Q = \frac{f_0}{BW}$$

Bandreject Filter

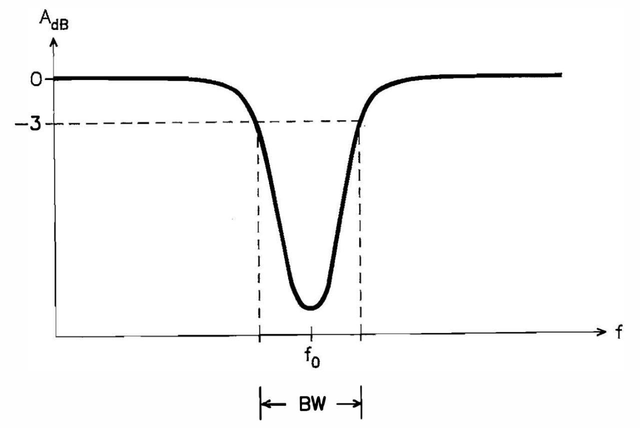


Figure: Bandreject Filter

Combinations

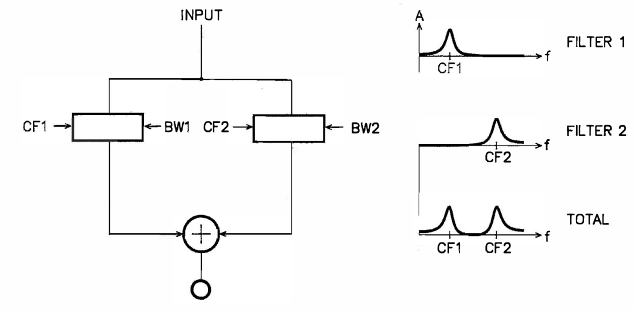
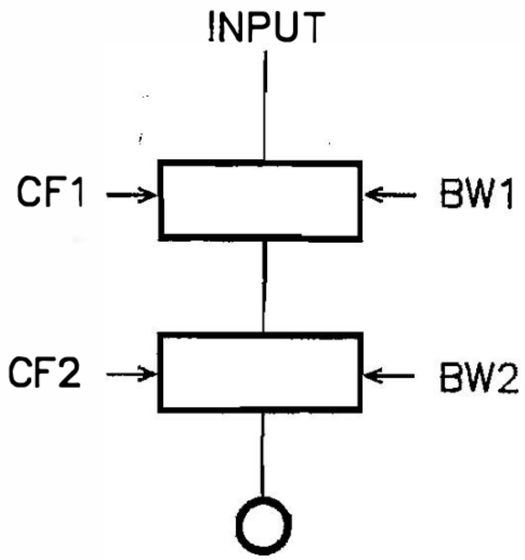


Figure: Parallel connection of filters

Combinations



Combinations

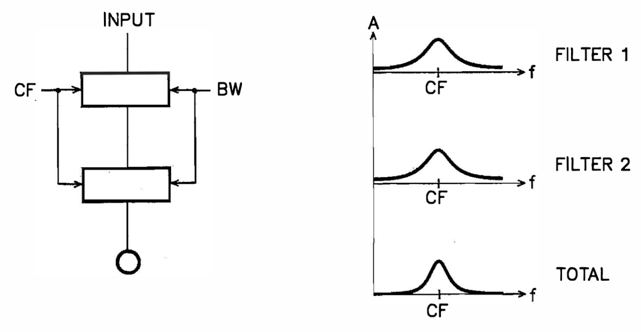


Figure: Cascade connection of identical filters

Combinations

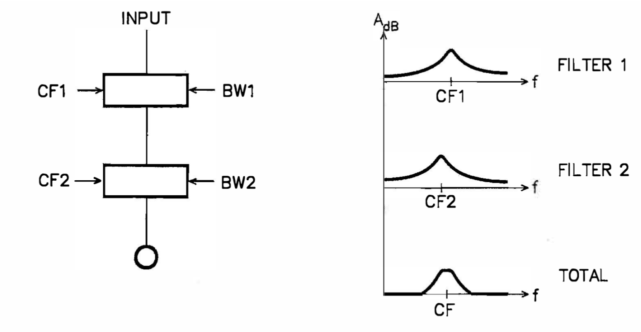


Figure: Cascade connection of two filters with slightly offset center frequencies

Combinations

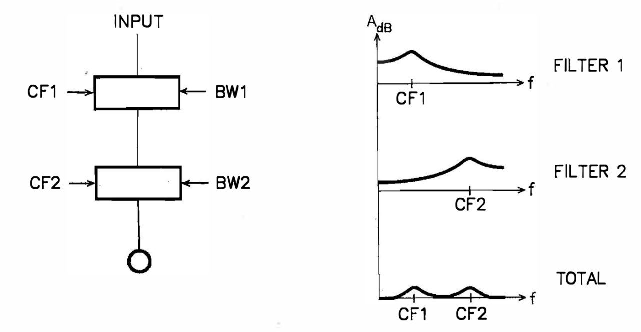


Figure: Cascade connection offilters whose passbands do not overlap

Testing - Quick Answers

1. Why is white noise a signal that is particularly suited to subtractive synthesis?
2. Which frequencies are attenuated when using a highpass filter with a cutoff frequency of 2000 Hz?
3. Which frequencies are attenuated when using a bandpass filter with a center frequency of 2000 Hz and a bandwidth of 4Hz?
4. What is the center frequency of a bandpass filter with cutoff frequencies at 300 and 3000 Hz?

References

- Charles Dodge & Thomas A. Jerse: Computer Music. Synthesis, Composition and Performance. Shirmer, 1985
- Cipriani & Giri: Electronic Music and Sound Design. Volume 1