# Bob Moog ON SYNTHESIZERS

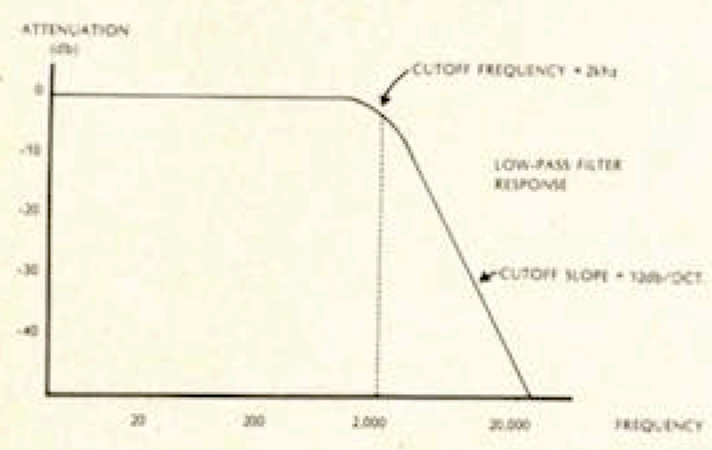
## Low-Pass Filters

Filters are barriers that allow some things to pass while inhibiting the flow of others. Homely examples are the coffee filter, which holds the grounds back while permitting the flow of brewed coffee, and tinted glass, which impedes the harsher components of sunlight without completely stopping the light.

Filters are common in electronics. They single out telephone conversations, tune stations in TV sets, separate the lows from the highs in speaker systems, and, of course, give synthesizers an incredible palette of tone colors. In all of these cases, the filters perform the same basic functions: they pass one part of the frequency spectrum of a signal and suppress the other part. Thus, filters are *spectrum* shapers. And that's all they are! Devices to remove noise, distortion, or wrong notes are not generally called filters.

An "ideal" electronic filter would pass the desired frequencies with no attentuation, noise, or distortion, and would completely stop unwanted frequencies. However, even if it were possible to construct an ideal filter (which it isn't), it wouldn't be as suitable for musical purposes as many of the simple "real" filters that are frequently used. In practice, synthesizer designers wind up doing the same thing with filters that they do with oscillator waveforms: they select simple characteristics that are musically useful, easy to control, and inexpensive to build. The whole idea of a mathematically perfect filter in an electronic musical instrument makes about as much sense as a musician striving to play "perfect" music—music without any fluctuation in pitch, rhythm, or loudness. Our ears and minds are geared to detect, analyze, and appreciate *departures* from mathematical perfection, in filters as in music itself.

The behavior of a filter is best described by its *response curve*, which is a graph showing how well the filter passes frequencies in different parts of the spectrum. As an example, here is the response curve of a low-pass filter.

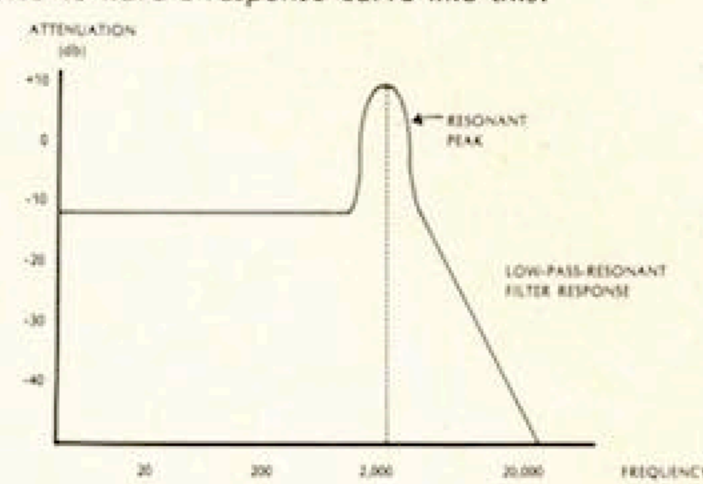



The vertical axis shows the amount of attenuation, while the horizontal axis gives the frequency. As you can see, a low-pass filter allows the lower portion of the frequency spectrum to pass without significant attenuation, but attenuates the upper portion. The frequency above which the amount of attenuation increases rapidly is called the *cutoff frequency*, while the characteristic rate at which the attenuation increases as the signal frequency goes above cutoff is called the *cutoff slope*.

The response curve above shows a filter with a cutoff frequency of 2khz (2,000 vibrations per second) and a cutoff slope of 12 decibels per octave of frequency change. (When the level of a sound is increased by 3db, its energy doubles.) If a 1khz sawtooth wave (about two octaves above middle C) were passed through the filter, its second harmonic would be slightly attenuated, and the higher harmonics would be attenuated to a much greater extent. The filtered wave would thus have reduced harmonic content, and sound less bright and edgy than the raw sawtooth. As the pitch of the sawtooth wave is lowered, more and more harmonics are allowed through by the filter. What happens to the tone color? The answer is that it *seems* to remain fairly constant! The action of the filter on the sawtooth wave, and not the strengths of the harmonics *per se*, determines the timbre. In other words, a filter often has a "sound" of its own, even though it is a sound modifier. This is analogous to stained glass (an optical filter), which has a distinct color that seems to remain fairly constant even if the color of the light shining through it changes.

Low-pass filters most frequently have slopes of 6, 12, or 24 decibels per octave. Each has its own sound, and I am not going to try to describe them. The tone controls on a stereo set or guitar amplifier are 6 decibels per octave, whereas most high-quality synthesizers employ a 24 decibels-per-octave low-pass filter.

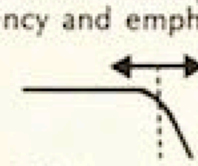
It happens to be easy, as well as musically powerful, for the musician to change the *shape* of the response curve from low-pass to resonant. A low-pass filter with emphasis (or resonance) control can be adjusted to have a response curve like this:



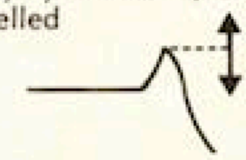

Now the filter emphasizes a narrow band of frequencies, slightly attenuates those below resonance, and sharply attenuates those above resonance. The sound is completely different from that of a regular low-pass filter.

Depending on the sharpness and position of the resonant response peak, the sound can be vocal, nasal, or oboe-like, or can have a distinctive but completely new quality.

The two panel controls generally associated with a synthesizer low-pass filter (*cutoff frequency* and *emphasis*) are of great importance to synthesizer musicians, for they, more than any other controls, determine the instrument's timbre. In addition, the fact that they can be varied during performance means that the performer can shape tone color in ways that are basically different from those available to acoustic-instrument performers. On many synthesizers, the cutoff frequency and emphasis controls are labelled



and



respectively, to remind performers that these controls are direct handles on the low-pass filter response characteristic.

Synthesizer tone oscillators are generally voltage-controlled. That is, their pitch changes in response to electrical signal variations. This is how synthesizers produce pitch swoops, glides, note patterns, vibrato, and other "electronic" patterns. Voltage-controlled filters (VCFs) have the same musical versatility. A filter that is voltage-controlled by a slow sine wave will impart tremolo to a tone. A control signal that rises abruptly and falls gradually will cause a low-pass filter to allow more harmonics to pass at the beginning of a sound than at the end, thus imparting a strong percussive texture to the sound. Voltage-controlled filters thus offer the musician the means for imparting wide-range, rapid, and precise variations on the spectra of musical sound, for yet another new musical resource. Most synthesizer sounds that we hear rely heavily on voltage-controlled filtering.