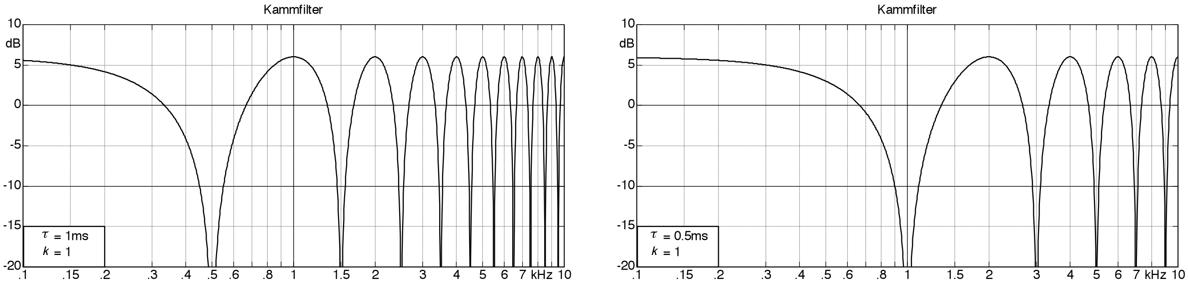
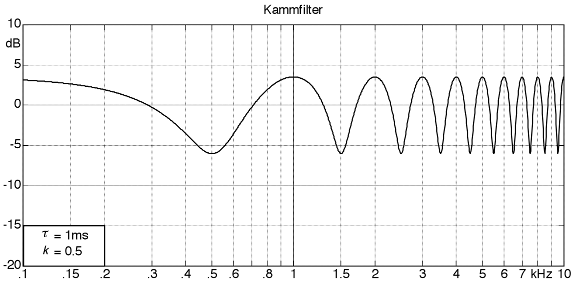
10.8.3 Phaser / Flanger / Chorus

Since the first electric guitars came into service, there was also the wish for sound-modifications. First, there was only a “tone”-control (a potentiometer with a capacitor), then more sophisticated sound filters were added, followed by electronic vibrato, tremolo, echo, and reverb. The typical guitar-**echo** results from periodic signal repetitions (about 50 – 500 ms delay-time), simple **reverb** combines several echo sequences of differing periodicity, high-quality reverb is generated by springs (10.8.1) or digital signal processors (in the studio, reverb-plates or reverb-chambers are used, as well). **Phaser**, **flanger** and **chorus** are electronic effects based on a short delay. The **delay** is a linear system that delays signals. A **short time-delay** sets the signal back by a few milliseconds, and therefore is different from an echo-system.

For phaser-, flanger- and chorus-devices, the delayed signal is added to the original signal such that a **comb-filter** results. The name is derived from the fact that the magnitude-frequency-response has a remote similarity to the teeth of a comb (**Fig. 10.8.17**). Plotted against a linear division of the frequency axis, the maxima and minima alternate in equal frequency distances; the figure, however, shows the logarithmic frequency scaling as it is preferred in electro-acoustics. Apart from the basic gain (not that important), two parameters determine the filter behavior.: the **delay-time** τ and the **delay gain** k. Varying τ will change the frequencies at which the maxima and minima occur (i.e. the distance between the notches in the frequency spectrum), while k governs by how many dB the gain factor changes (i.e. how deep the notches are). For a negative k, the first minimum is at $f = 0$.





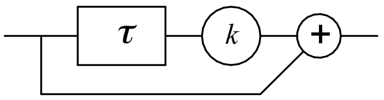


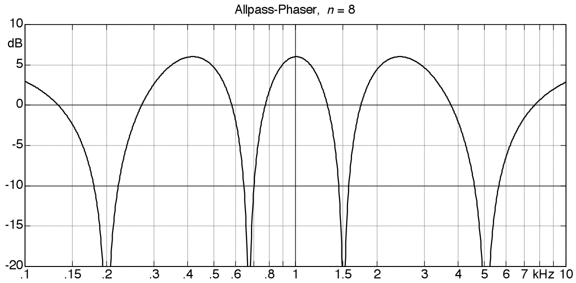
Fig. 10.8.17: Comb-filter: frequency responses and signal-flow diagram (block-diagram).

The comb-filter is in fact a typical **interference filter**: for a sine signal, a delay of half a period leads to a cancellation (or attenuation). A delay of a whole period causes amplification. Maxima and minima repeat with the period of the frequency: a minimum occurs with a delay of 1.5, 2.5, 3.5, … (or generally $n + 0.5$ with $n = 0, 1, 2, ...$) periods of the sine-signal. For the maxima, the situation is similar. In systems theory, such a filter is also termed FIR-filter, due to its impulse response which is finite in the time domain: **F**inite **I**mpulse **R**esponse filter.

The special aspect about phaser / flanger / chorus is, however, not really to be seen in the periodical frequency response but in the variation of the latter over time. A low-frequency-oscillator (**LFO**) changes the delay-time τ periodically. For example, τ swings back and forth once per second between 1 ms and 2 ms, making each minimum and each maximum sweep across a certain frequency-range as a function of time. Strictly speaking, we encounter here a time-variant system the description of which is not entirely trivial – but the quasi-stationary approximation of the shifting comb-teeth (or notches) is good enough in practice. Adding original and delayed signal (positive k) positions the lowest-frequency minimum at the inverse of twice the delay-time (1ms ⇒ 500Hz). For too short a delay-time, there is barely any audible effect because small changes occur in the high frequency region only. For a **flanger**, a typical delay-time range is 1 … 5 ms, in extreme cases this may extend from 0,3 to 15 ms.

As the delay-time is increased to above about 20 ms, a new auditory perception is generated: the **chorus-effect**. As a first-order approximation, both flanger and chorus can be described with the block-schematic as given above. Due to the very short delay-time, the flanger generates relatively broad minima in the signal spectrum and thus predominantly changes the color of the sound. Conversely, the delay-time of the chorus approaches already the value where single echoes might be discernible. This occurs at about 50 ms delay-time; our auditory system can not yet distinguish echoes as such at $\tau = 25$ ms, but it recognizes already a "fellow player". This effect is the aim of the chorus: the slightly delayed repetition is intended to create the fuller sound of not just one but two instruments playing. In addition, the delay-time is modulated by the LFO (as it is in the flanger), creating an impression of a whole instrument-ensemble. The term chorus is derived from "choir"; in the latter the individual voices start at slightly different times and sing slightly different pitches. The **pitch change** (more exactly the frequency change) is the result of the time-variant delay-time $\tau(t)$. As τ increases, f decreases, as τ decreases, f increases. The relative de-tuning is calculated as the change of the delay-time over time: $\Delta f / f = -d\tau(t)/dt$. As an example: if τ rises linearly by 10 ms within 0,5 s, the frequency of the delayed signal is decreased by 2%. A delay modulation in the shape of a triangle generates a back-and-forth sweep in the pitch. With a subtle mixing-in of the chorus (slow modulation, small frequency shift) the desired wavering choir effect is generated. For extreme settings a whining frequency modulation becomes audible.

The **phaser** is similar to the flanger but uses all-pass circuits to generate the delay; these all-passes were originally created using active circuitry (**Fig. 10.8.18**). The RC-combination determines the delay – with the R being the controllable element (as LDR or FET). Since a 1st-order all-pass can only shift the phase by 180°, several all-pass circuits need to be connected in series: n = 6…10 would be a typical number. In contrast to the flanger, the minima are not equidistant, and fewer interference notches of greater width are created..



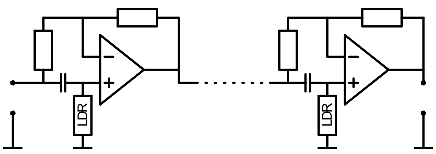


Fig. 10.8.18: All-pass phaser