## 10.3.2 Equalizer (EQ)

A filter that allows for narrow-band changes in the spectrum (or in the transmission function) is called an equalizer. Besides a basic gain that we assume to be 1 ($\hat{=}$ 0dB) in the following, there are 3 parameters that define the transmission behavior of an equalizer: center-frequency, boost and Q-factor (**Fig. 10.3.17**) The center-frequency $f_x$ is the **frequency** at which the gain assumes it maximum (or minimum) value, the **boost** $\beta$ specifies the gain at $f_x$, and **Q-factor** $Q$ determines the bandwidth. For a so-called parametric equalizer (EQ), all three parameters are adjustable while for a so-called graphic EQ, only $\beta$ is variable, with $f_x$ and $Q$ fixed at predetermined values.

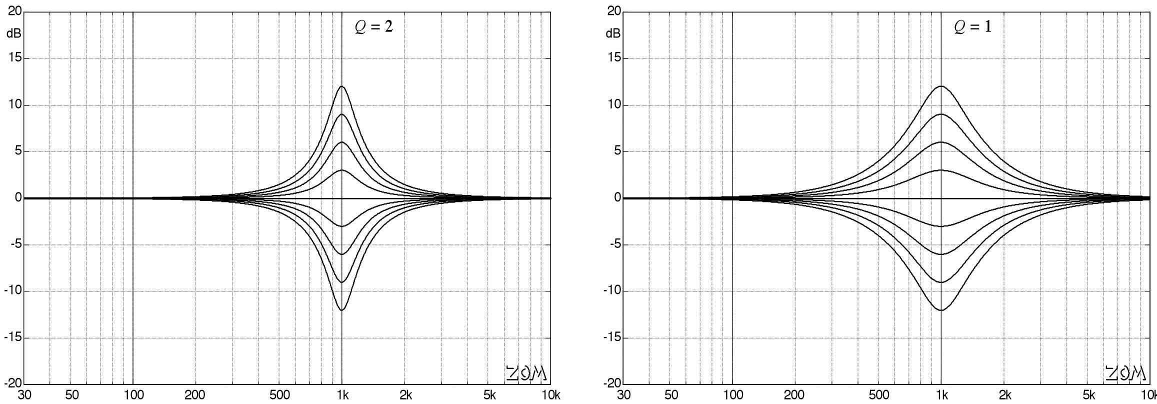


**Fig. 10.3.17:** Equalizer characteristic. $B = 20\cdot\lg(\beta)$ = [-12 -9 -6 -3 0 3 6 9 12]dB, $f_x$ = 1 kHz.

In Fig. 10.3.17 we see two different groups of curves. $f_x$ and $B$ are self-explanatory, but the Q-factor requires some supplementary comments. Often, the Q-factor is determined from the relative bandwidth measured as the distance of the -3-dB-points on the graph. This definition is, however, useless for an EQ e.g. because for a 2 dB-boost no -3-dB-points can be defined at all. The correct definition results from the transmission function $\underline{H}$:

$$\underline{H} = \frac{\omega_x^2 + p\cdot\omega_x / Q_Z + p^2}{\omega_x^2 + p\cdot\omega_x / Q_N + p^2} \qquad p = j\cdot 2\pi f \qquad \omega_x = 2\pi f_x$$

As can be seen, this filter has a pole-Q-factor $Q_N$ and a zero-Q-factor $Q_Z$. For $f = f_x$, we get $b = Q_N / Q_Z$. In order to define *one single* Q-factor for an equalizer, an infinite number of possibilities present themselves; customary are two (different!) definitions. Either we keep the denominator-Q-factor constant and vary the boost-factor via the numerator-Q-factor; this filter-type is called **constant-*Q*-equalizer**, and the denominator-Q-factor is specified as the Q-factor of the equalizer. Or we link numerator- and denominator-Q-factors via $Q_Z = Q/\sqrt{\beta}$ and $Q_N = Q\cdot\sqrt{\beta}$ ; in this case we specify as Q-factor of the equalizer: $Q = \sqrt{Q_N \cdot Q_Z}$ . Connecting two equalizer of the second variety in series with $f_x$ and $Q$ correspondingly identical in both EQs, and the boost-factors set reciprocally ($\beta_1 = 1/\beta_2$), the effects of these two equalizers compensate each other completely. They are inverse to each other, and therefore this EQ-type is also called **inverse EQ** (the filter shown in Fig. 10.3.17 is of this type). For the constant-*Q*-equalizer, however, a corresponding series-connection does not lead to a complete compensation: the attenuation is of a smaller bandwidth than the amplification (**Fig.10.3.18**). These differences (if they are of any importance at all) play a role only for graphic EQs, because all parameters can be freely adjusted in the parametric EQ, anyway.

 

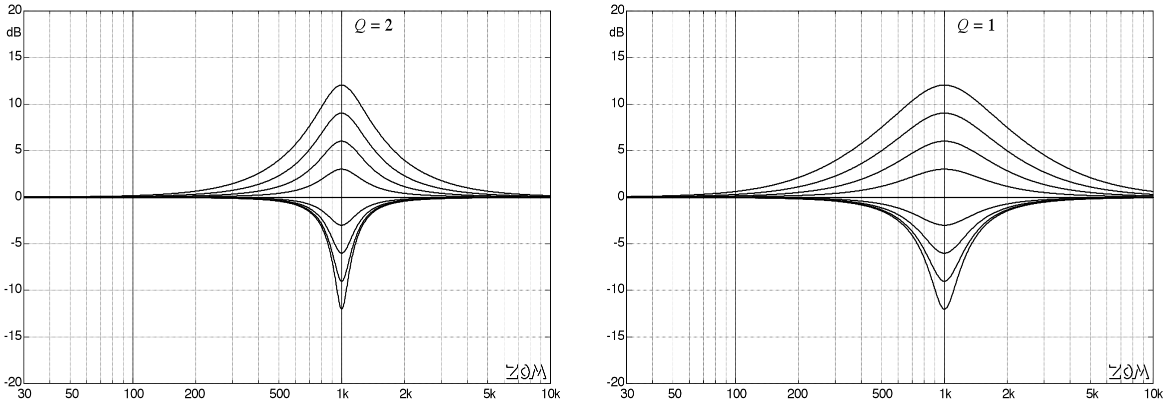


**Fig. 10.3.18:** Characteristic of a Constant-*Q*-Equalizer. The specified Q is the denominator-Q.

The constant-*Q*-equalizer is held in high esteem because the Q-factor does not increase as the boost-factor grows but remains constant independent of the boost. It should be added that it is the denominator-Q-factor that remains constant because the numerator-Q-factor of course does change. It is not entirely far-fetched to give priority to the denominator-Q over the numerator-Q because the **decay-coefficient** determining the time-envelope of a step- or an impulse-response indeed does depend only on the denominator-Q. However, whether it is in fact desirable that abutting EQ-bands show a boost-dependent, more or less pronounced overlap as depicted in Fig. 10.3.18, needs to be determined on a case-by-case basis according to individual preferences.

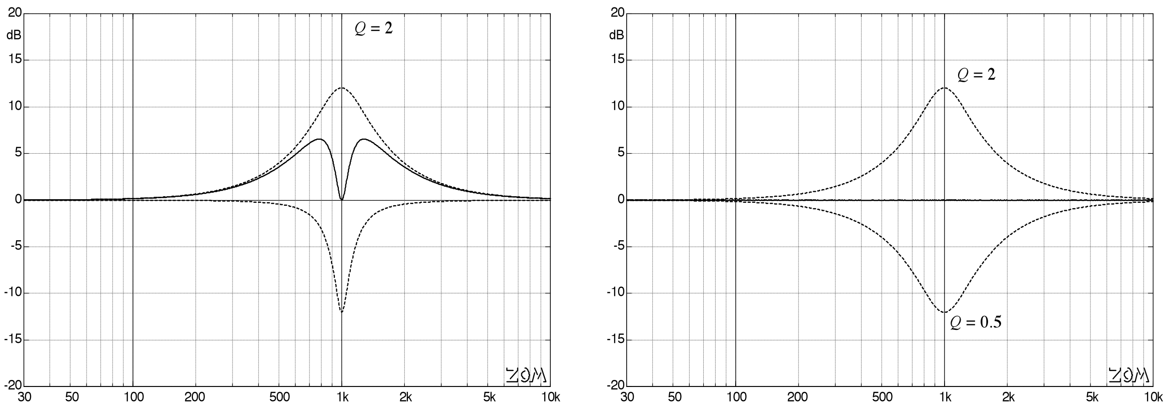


**Fig. 10.3.19:** Series-connection of two constant-*Q*-equalizers. Single filter (----) and series connection (——). For the gain to add up to 0, both Q-factors need to be reciprocal (right-hand picture).

**Fig. 10.3.20** shows a circuit often utilized for designing graphic EQs. The frequency-dependent impedance *Z* of the resonant circuit may be realized in a passive (RLC) or an active manner; the latter via adding an additional amplifier. The boost-factor can be controlled with the potentiometer *P*, the center-frequency and the Q-factor are pre-set by the circuit design.

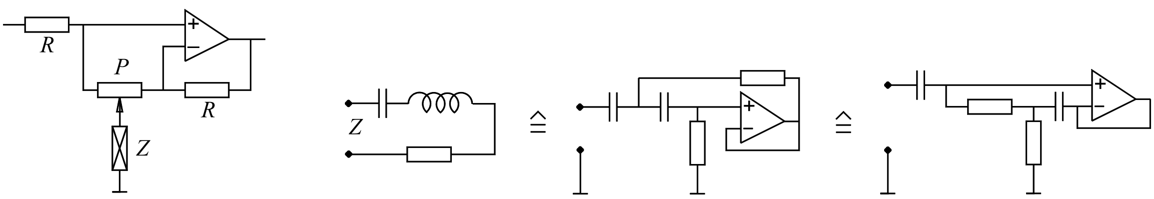


**Fig. 10.3.20:** Active EQ-circuit. The series-resonance-circuit (*Z*) may be realized via either active circuit. The active resonant circuits are approximations of an ideal series-resonance circuit

 Translated by Tilmann Zwicker

The circuit presented in Fig. 10.3.20 offers the possibility to vary Q (within certain limits) depending on the boost-factor (**Fig. 10.3.21**). As can be seen, we obtain inverse behavior with a bandwidth varying in detail. Relatively high impedance in the potentiometers results in the characteristic as show on the right, and low-impedance pots give the curves on the left. For linear potentiometers, the boost-value changes predominantly towards the end to the control path – therefore special pots with an S-shaped characteristic are required.

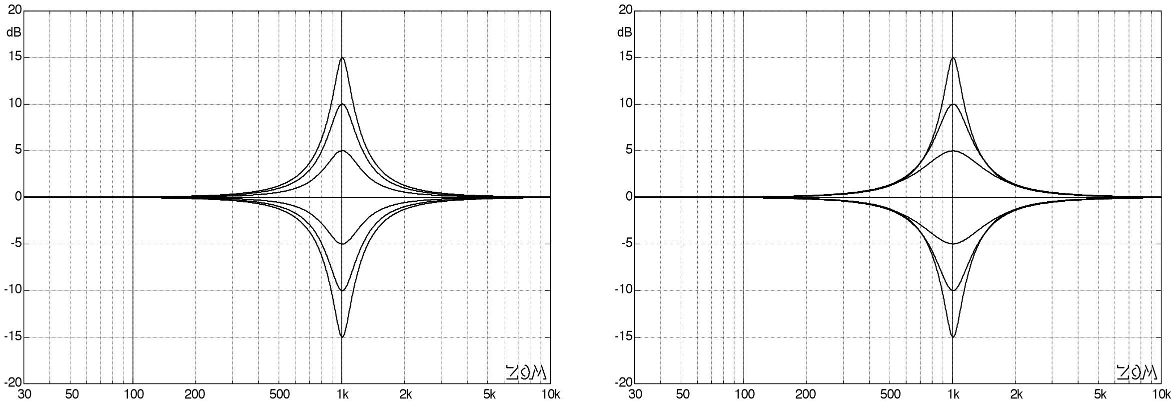


**Fig. 10.3.21:** Transmission characteristics of the EQ-circuit according to Fig. 10.3.20.

A multi-band graphic EQ may be designed with little effort by adding into the circuit according to Fig. 10.3.20 further potentiometers with corresponding different resonant circuits. **Fig. 10.3.22** has the corresponding diagrams for various settings.

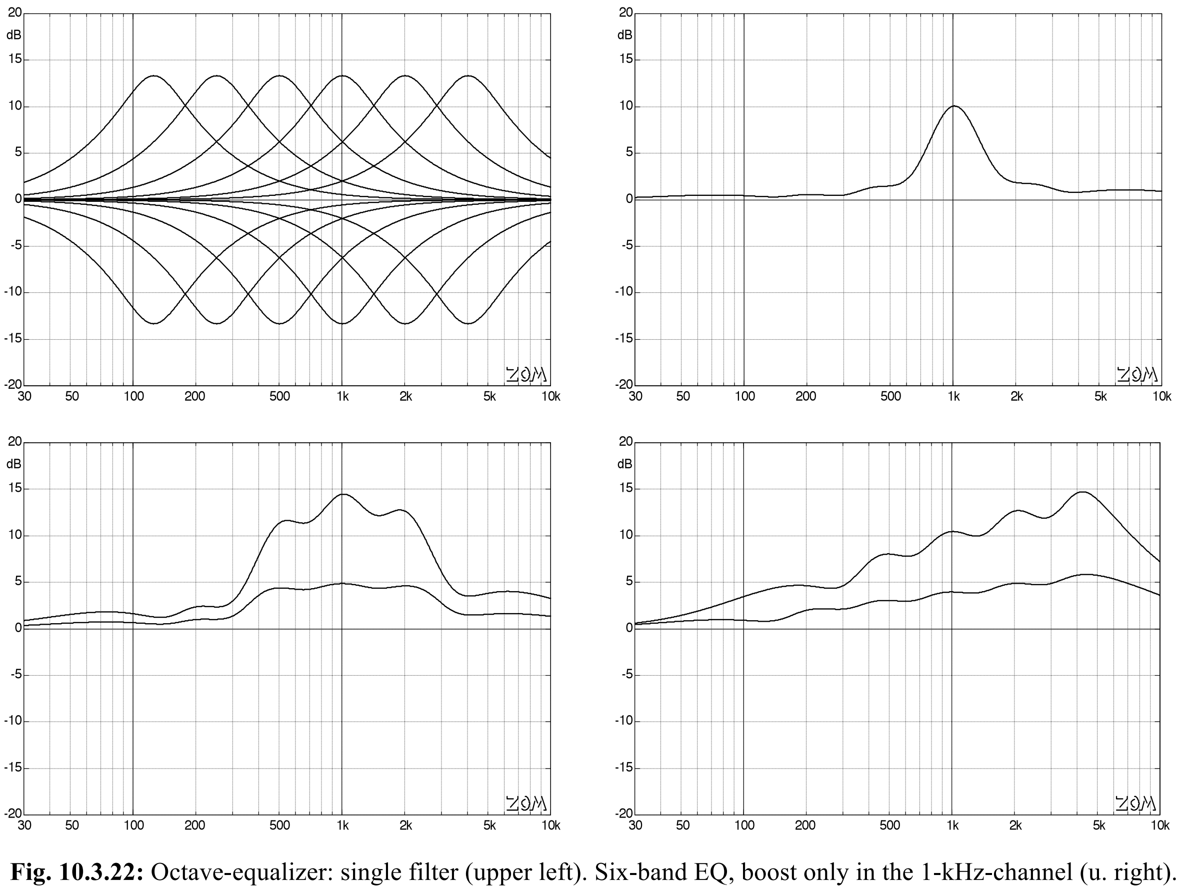


**Fig. 10.3.22:** Octave-equalizer: single filter (upper left). Six-band EQ, boost only in the 1-kHz-channel (u. right). Boost only in 3 bands (lower left). Boost increasing with frequency (l. right).

 