transformation given by

$$s = \frac{2}{T}\frac{z-1}{z+1}. \tag{5.26}$$

Tables 5.2–5.5 contain the coefficients of the second-order transfer function

$$H(z) = \frac{a_0 + a_1 z^{-1} + a_2 z^{-2}}{1 + b_1 z^{-1} + b_2 z^{-2}}, \tag{5.27}$$

which are determined by the bilinear transformation and the auxiliary variable $K = \tan(\omega_c T/2)$ for all audio filter types discussed. Further filter designs of peak and shelving filters are discussed in [Moo83, Whi86, Sha92, Bri94, Orf96a, Dat97, Cla00]. A method for reducing the warping effect of the bilinear transform is proposed in [Orf96b]. Strategies for time-variant switching of audio filters can be found in [Rab88, Mou90, Zöl93, Din95, Väl98].

**Table 5.2** Low-pass/high-pass/band-pass filter design.

| Low-pass (second order) | | | | |
|---|---|---|---|---|
| $a_0$ | $a_1$ | $a_2$ | $b_1$ | $b_2$ |
| $\frac{K^2}{1+\sqrt{2}K+K^2}$ | $\frac{2K^2}{1+\sqrt{2}K+K^2}$ | $\frac{K^2}{1+\sqrt{2}K+K^2}$ | $\frac{2(K^2-1)}{1+\sqrt{2}K+K^2}$ | $\frac{1-\sqrt{2}K+K^2}{1+\sqrt{2}K+K^2}$ |
| **High-pass (second order)** | | | | |
| $a_0$ | $a_1$ | $a_2$ | $b_1$ | $b_2$ |
| $\frac{1}{1+\sqrt{2}K+K^2}$ | $\frac{-2}{1+\sqrt{2}K+K^2}$ | $\frac{1}{1+\sqrt{2}K+K^2}$ | $\frac{2(K^2-1)}{1+\sqrt{2}K+K^2}$ | $\frac{1-\sqrt{2}K+K^2}{1+\sqrt{2}K+K^2}$ |
| **Band-pass (second order)** | | | | |
| $a_0$ | $a_1$ | $a_2$ | $b_1$ | $b_2$ |
| $\frac{\frac{1}{Q}K}{1+\frac{1}{Q}K+K^2}$ | 0 | $-\frac{\frac{1}{Q}K}{1+\frac{1}{Q}K+K^2}$ | $\frac{2(K^2-1)}{1+\frac{1}{Q}K+K^2}$ | $\frac{1-\frac{1}{Q}K+K^2}{1+\frac{1}{Q}K+K^2}$ |

## 5.2.2 Parametric Filter Structures

Parametric filter structures allow direct access to the parameters of the transfer function, like center/cutoff frequency, bandwidth and gain, via control of associated coefficients. To modify one of these parameters, it is therefore not necessary to compute a complete set of coefficients for a second-order transfer function, but instead only one coefficient in the filter structure is calculated.

Independent control of gain, cutoff/center frequency and bandwidth for shelving and peak filters is achieved by a feed forward (FF) structure for *boost* and a feed backward