Tone controls and filters

Tone controls may be used either because of technical shortcomings in the programme source or in the listener's equipment or simply because the user prefers the sound of a modified tonal balance. The inclination to use tone controls for the latter reason arises particularly with music other than that of a straightforward concert or recital type, for when multi-track recording, artificial reverberation, response manipulation, etc. are used, and some of the instruments are partially or wholly electronic, the concept of fidelity to the original sound simply has no meaning.

Some faults which may call for the use of tone controls or filters are:

(1) Less-than-ideal balance of musical bass and treble due to poor acoustics or microphone placement.

(2) Male speech with too much bass, sometimes caused by speaking too close to ribbon microphones. Broadcast talks often have this fault.*
(3) Non-level frequency response in broadcasting or recording equipment, due to imperfectly equalised landlines, microphones with non-uniform h.f. response, particularly for sounds arriving well off-axis, incorrectly maintained disc cutters, etc.
(4) Falling loudspeaker bass-response, especially with small bookshelf loudspeakers.
(5) Rumble from turntables, or caused, for example, by structure-borne vibrations from piano pedals reaching the microphone stand.
(6) Presence of noticeable background noise (hiss) due to weak radio signals or recording noise.
(7) Non-linearity distortion; this usually tends to be worst at high frequencies, especially with gramophone records.

The last three items are different from the others because musical balance is not directly involved and their optimum mitigation calls for the use of sharp-cutting filters rather

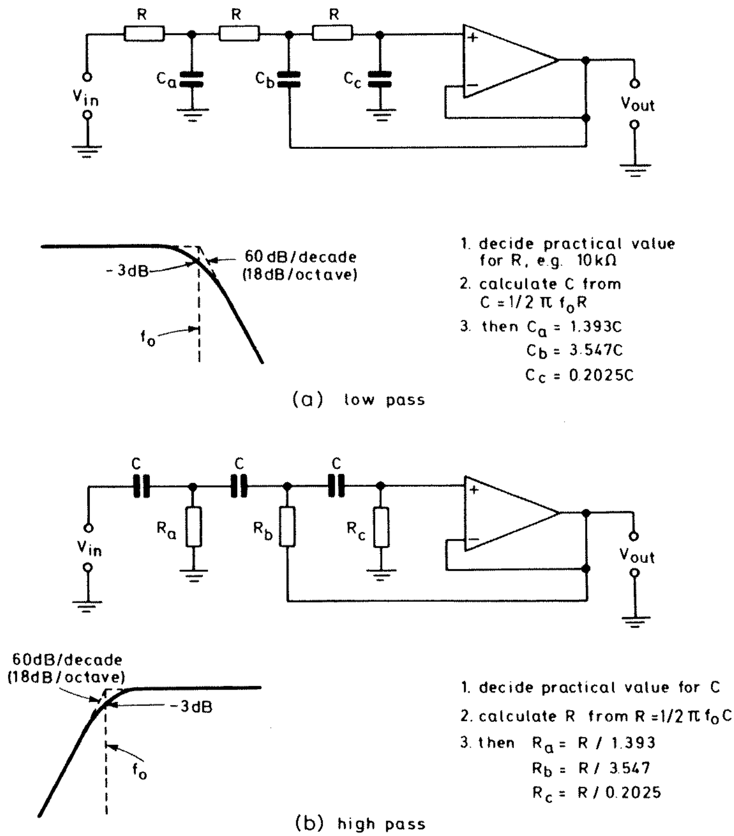

Figure 14.21 Sallen and Key active filters giving third-order Butterworth response. 741 type operational amplifiers may be used

* Speech is, more often than not, reproduced at an unnaturally high level, and this causes it to sound too bassy even in the absence of such a transmission fault.

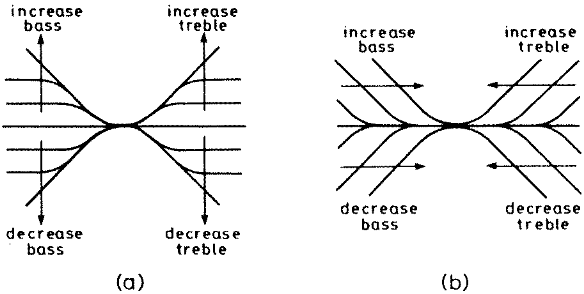

Figure 14.22 Two basic types of tone-control characteristic

than tone controls—the latter are usually incapable of providing a rate of roll-off exceeding 20 dB/decade (6 dB/octave). Third-order Butterworth filters are very suitable, and *Figure 14.21* shows active-filter circuits giving accurate responses of this type.[20]

Tone controls usually permit independent adjustment of bass and treble response to be made and the exact manner in which these responses may be varied depends on the

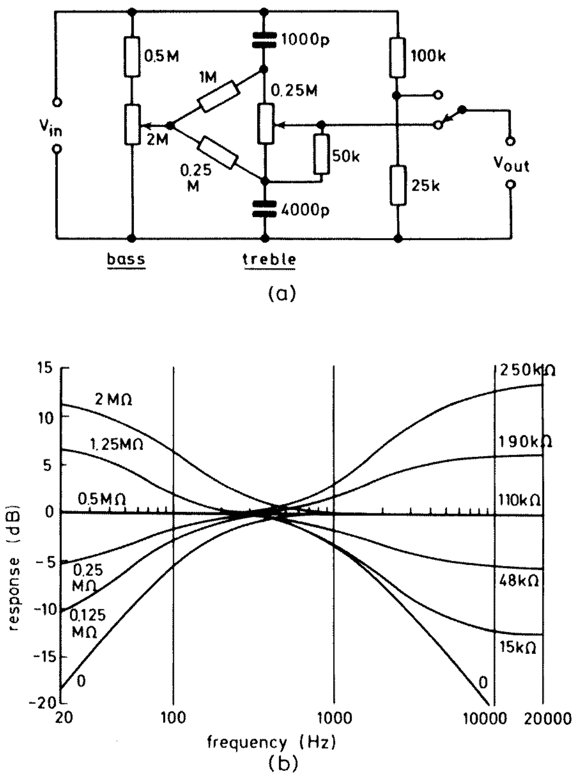

Figure 14.23 Voigt tone control, published in 1940

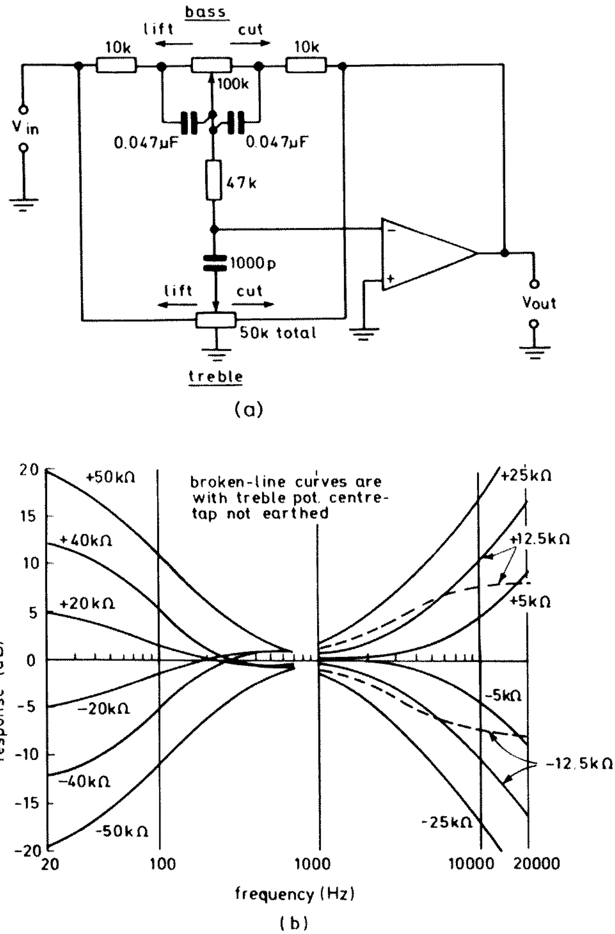

Figure 14.24 Baxandall tone control, published in 1952. To suit solid-state usage, the impedances have all been reduced by a factor of 10 compared with those in the original valve version. A resistor, e.g. 2·2 kΩ, in series with the 1000 pF capacitor may be necessary for h.f. stability when using operational amplifiers

type of circuit employed.[21] Two limiting cases are shown in *Figure 14.22*. For adjustment of the general bass/treble musical balance, the (*a*) type of characteristic is usually the more suitable, but for items 2, 4, and possibly 3 in the above list, the (*b*) form of variation is likely to be preferable. In economical equipment not fitted with separate filters, the adoption of a tone control of the (*b*) type enables it to take over the filter function tolerably well.

The desirability of independent bass and treble tone controls has been recognised for a long time, Voigt having designed such a circuit, with switch controls, in 1933. His later (1940) smoothly adjustable circuit[22] is shown in *Figure 14.23*, with measured response curves, which are approximately of the *Figure 14.22(a)* type. Note the 'cancel' switch, to enable instant comparison with the uncorrected response to be made—a facility also provided in the *Figure 14.15* control unit.

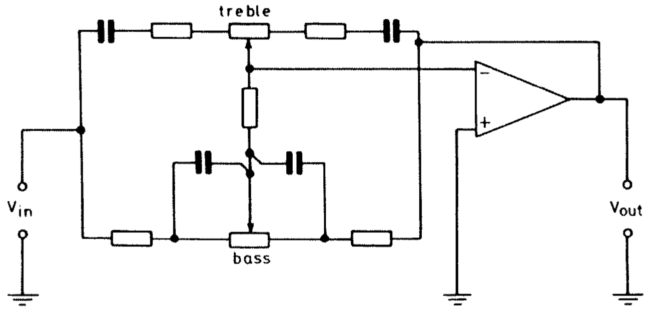

Figure 14.25 Earlier form of Baxandall tone control, now in widespread use

As with disc equalisation, there are considerable advantages in employing negative feedback in tone-control circuits, and the most widely used configuration is based on a design evolved by Baxandall about 1950.

The original published design[23] is shown in *Figure 14.24*, though the impedance values have been reduced by a factor of 10 to make them more typical of solid-state practice. The cheapest versions employ just a single transistor, but lower distortion and lower output impedance may be obtained by using a transistor pair, or an integrated circuit

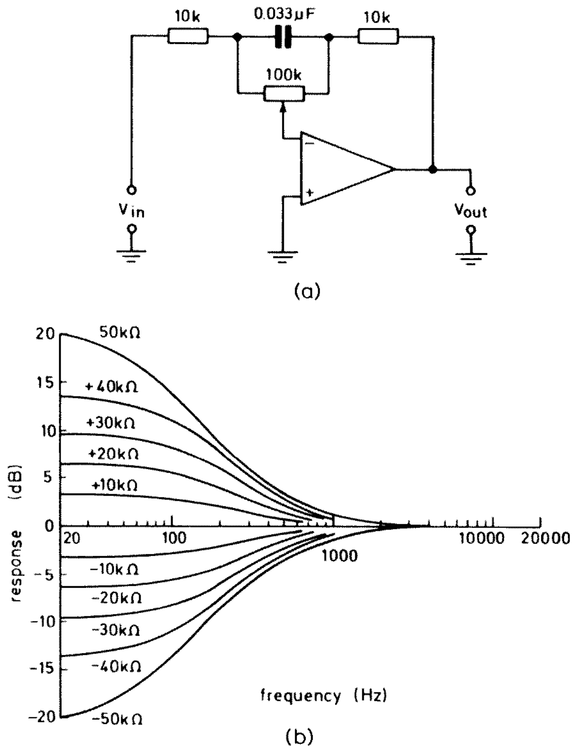

Figure 14.26 Bass-only tone control

operational amplifier as here shown. In practice, it is desirable to add blocking capacitors to prevent the flow of base current etc. in the control potentiometers, otherwise scraping noises are liable to occur when the knobs are rotated.

The use in *Figure 14.24* of a centre-tapped treble potentiometer leads to treble-control characteristics of the *Figure 14.22(b)* type. It was pointed out in the original article, however, that by adding a switch in the centre-tap lead, the alternative characteristics of *Figure 14.22(a)* could be made available; and such a switch was indeed provided in a practical control unit designed by Baxandall.[24] In more recent times, with general improvement in the h.f. performance of microphones, loudspeakers, landlines, and radio

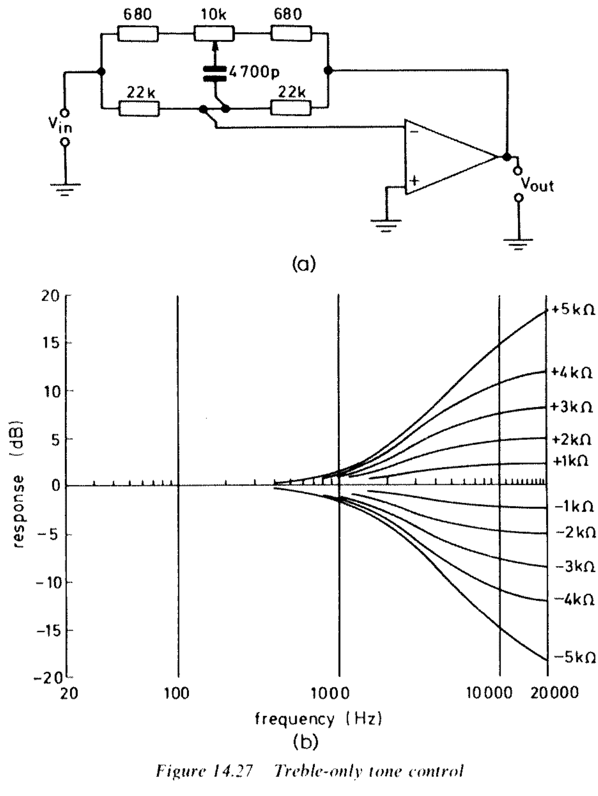

Figure 14.27 Treble-only tone control

and recording systems, the need for the *Figure 14.22(b)* type of treble-control characteristic has greatly diminished, and most present-day control units provide only an approximation to the *(a)* type of treble characteristic.

The tone-control circuit configuration now most widely used is either that of *Figure* 14.24 with the treble-control centre-tap omitted, or it is the alternative configuration shown in *Figure 14.25*. (The latter arrangement, including the range-limiting resistors shown in series with the treble potentiometer, is in fact that first used by Baxandall in 1950, the change to the former being made shortly afterwards largely on the grounds that it saved a capacitor. A further year or two elapsed before the idea of using a centre-tapped potentiometer to obtain the *Figure 14.22(b)* type of characteristic was hit upon.)

The bass-control characteristics given by these circuits approximate to the *Figure 14.22(b)* type, though the actual curve shapes at intermediate cut and lift settings are more

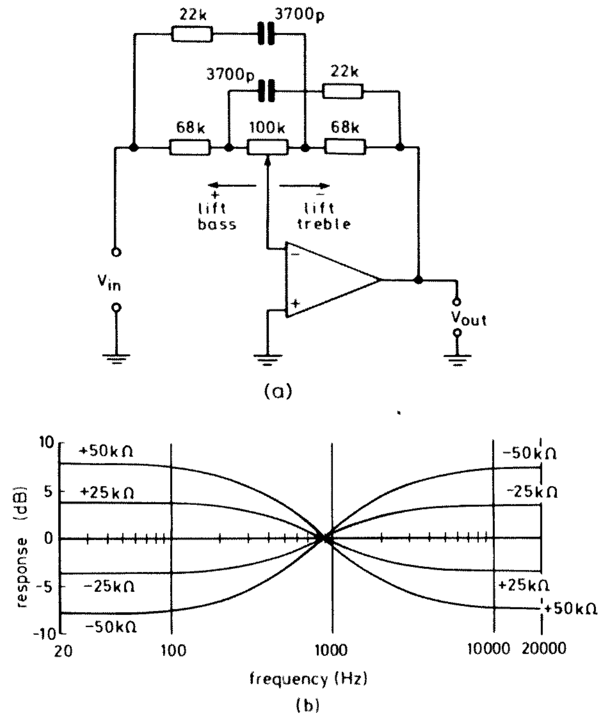

Figure 14.28 Ambler tone-balance control

complex, as shown in *Figure 14.24*. Such characteristics have been retained in most contemporary designs, perhaps because of the prevalence of faults such as 2, 4, and 5 above. It is, however, quite possible to obtain the *Figure 14.22(a)* type of bass characteristic if preferred, and a bass-only tone control of this sort is shown in *Figure 14.26*.* This may be combined with a treble control in the same circuit, but impedance ratios tend to become rather large if interaction between the controls is to be kept small, and this may degrade the noise performance more than is desired. Now that transistors and integrated circuits are so cheap, there is much to be said for employing separate circuits for bass and treble. A suitable circuit giving treble control only is shown in *Figure 14.27*.

A feedback tone control of an unusual kind, due to Ambler,[25] was published in 1970. The ingenious circuit of this single-knob 'tone-balance control' is shown in *Figure 14.28* together with curves.

*This gives curves whose shape conforms accurately to a simple transfer function of form $(1+pT_1)/(1+pT_2)$, but the upper corner frequency does vary slightly with knob setting.