Tone-balance Control

A different kind of characteristic, to suit "difficult" programme material

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It seems to the writer that there are occasional programme sources, both records and radio, that do not sound correctly balanced as between bass and treble, yet there is no obvious harmonic distortion and the condition cannot be satisfactorily corrected by the usual type of bass and treble tone controls.

If the bass is originally too strong and the treble too weak, normal bass cut and treble boost may be applied: however this removes too much of the extreme bass, provides too much extreme treble, and still leaves the bass in general too strong and the treble in general too weak. The opposite effect may also occur, when the bass is originally too weak and the treble too strong. These effects are more often but not invariably found when the programme source is on older or cheaper gramophone record, or a radio programme from one of the less usual concert halls involving land-lines which may be longer or less well equalised.

The type of tone control usually included in a high-fidelity audio assembly always operates more powerfully on the extreme bass and treble parts of the audio spectrum than on the less extreme parts. This characteristic is shown by both the passive type of network exemplified by William-son's circuit [1] and by the feedback type of system such as Baxandall's. [2] In both these circuits separate bass and treble controls are provided.

It occurred to the writer that a tone-balance control would be useful in the circumstances described above, which at one end of its range boosts the whole of the bass fairly uniformly, slopes across the middle frequencies, and cuts the whole of the treble fairly uniformly. At the centre of its range it should provide a flat frequency response and unity gain, and at the other end of its range bass cut, slope across the middle, and treble boost. A negative-feedback system would be preferred, to minimize distortion.

A basic tone-balance control system which meets these requirements is shown in *Fig. 1(a)*. At low frequencies where the admittance of the capacitors has become negligibly small, the circuit reduces to that shown in *Fig. 1(b)*. Moving the potentio-meter slider to the left reduces the input resistance and increases the feedback resistance, hence giving a uniform boost at these
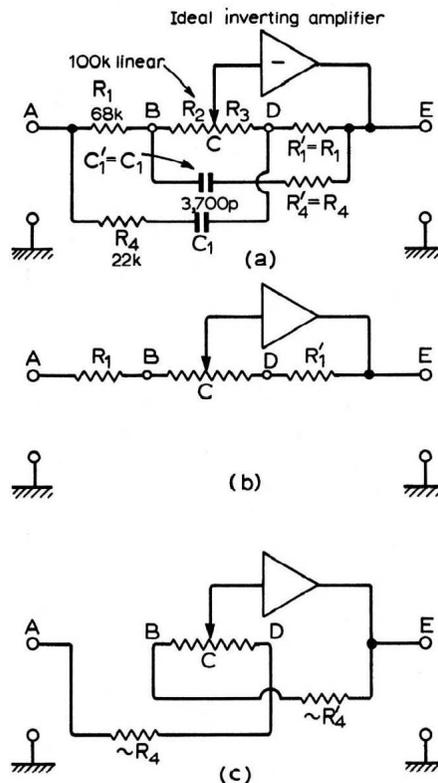

Fig. 1. Basic tone balance control system (a); exact equivalent at low frequencies (b); and approximate equivalent at high frequencies (c).

low frequencies. Moving the slider to the right gives a uniform bass cut. At high frequencies, where the impedance of the capacitors has become negligibly small, the circuit approximates to that shown in *Fig. 1(c)*, as R_4 has a lower value than R_1. Here at the "input" and "feedback" ends of the potentiometer have been reversed, so movement of the slider to the left gives a uniform treble cut to go with the bass boost and movement to the right gives a uniform treble boost to go with the bass cut. It seems reasonable to assume the smooth transition between the cut and boost condotions at any one setting of the potentiometer as the frequency is varied, and also that the system gain will be equal to (−1) at all frequencies with the potentiometer centred, and hence with the input / feedback network symmetrical. These assumptions are in fact confirmed by a detailed analysis.

If the usual assumption is made that the

amplifier is an ideal inverting amplifier so that its input voltage and input current are both negligibly small, it can be shown by consideration of the voltage at the junction point and current, in each arm of the network that system gain equals

$$\frac{V_E}{V_A} = -\frac{R_1R_2+(R_1+R_3)(R_4+1/j\omega C_1)}{R_1R_3+(R_1+R_2)(R_4+1/j\omega C_1)} \quad (1)$$

from which

$$\frac{V_E}{V_A} =$$

$$-\sqrt{\left[\begin{array}{c}\frac{(R_1R_2+R_1R_4+R_3R_4)^2+}{(R_1R_3+R_1R_4+R_2R_4)^2+}\\ \frac{(R_1+R_3)^2/\omega^2C_1^2}{(R_1+R_2)^2/\omega^2C_1^2}\end{array}\right]} \quad (2)$$

If $\frac{V_E}{V_A} = -1$, equation (2) reduces to

$$0 = (R_3-R_2)(2R_1+R_2+R_3)$$

$$\left[\frac{1}{\omega^2C_1^2}+R_4^2-R_1^2\frac{R_2+R_3+2R_4}{R_2+R_3+2R_1}\right] \quad (3)$$

There are two practical conditions for unity gain. The first is $R_2=R_3$; i.e., with the potentiometer centred. This is inde–pendent of frequency. The second is with the right–hand bracket equal to zero and it shows a unity gain crossover frequency which is independent of the setting of the potentiometer.

The component values required to give the desired response were calculated from equations (2) and (3). After choosing (some-what arbitrarily) a value of 100kΩ (linear) for the potentiometer R_2+R_3, the value of R_1 was calculated to frequencies at four different potentiometer settings: these results are shown graphically in *Fig. 2* together with the flat response produced with the potentiometer centred.

It is obvious that a lower impedance level could be used in the input feedback network, but there are disadvantages in going too low. A potentiometer value of 20kΩ or 50kΩ would be satisfactory, with the other values altered to suit. The value of 100kΩ arose when the circuit was first being developed and tested. A greater maximum boost or cut was originally allowed for, and then found in practice to be unnecessary and indeed undesirable. The values given are perfectly satisfactory, however, with a suitable amplifier. The system requires to be fed from a fairly low

impedance source (say $< 1\,k\Omega$) to avoid degradation of its response, and itself has a low output impedance ($< 1\,k\Omega$).

The tone balance control has been incorporated in an experimental mono tone control system, the circuit of which is shown in *Figs. 3-5*. The input stage *Fig. 3* is a slightly modified version of that published by Bailey [3] adjusted to suit the writer's signal sources. After the volume control, *Fig. 4*, comes an impedance conversion stage, followed by Baxandall type bass and treble controls, then the tone balance control, and finaly a feedback amplifier stage to raise the output level to the 4 volts peak-to-peak maximum needed to drive the Williamson amplifier [4] which the writer is still using. Like Mr. Linsley Hood [5] the writer has not come across any other amplifier which actually sounds better when driving moving-coil loudspeakers. A signal level through the control system of 200mV peak maximum is convenient, being well below the overload point and above the noise level.

The final stage in the control unit could be omitted if a more sensitive power amplifier were used, and the impedance conversion stage after the volume control could be omitted at the cost of a slight degradation of the response, particularly if treble boost is called for in the Baxandall tone control. However this impedance converter is a convenient point at which to insert a stereo balance control, as indicated in *Fig. 4*.

It should be noted that the whole of the signal network after the volume control in *Fig. 4* is floating at a level of about +6 V d.c. This has the advantage of saving capacitors. The savings are cost, space, and fewer unwanted phase shifts. There appears to be no significant disadvantage even with a series of stages in cascade, as in the present circuit: capacitors are needed only at the beginning and end of the series. The bypass capacitor in the bias network of each amplifier may be omitted if desired: the change in response is small as the bias

Fig.2. Calculated frequency response of tone balance control circuit shown in Fig. 1(a). A–R2 = 0, R3 = 100kΩ, B–R2 = 25kΩ, R3 = 75kΩ, C–R2 = R3 = 50 kΩ; D–R2 = 75 kΩ, R3 = 25kΩ, and E–R2 = 100kΩ, R3 = 0.

Fig. 3. Input stage (modified Bailey).

Fig. 4. Control unit incorporating tone balance control. Details of op. amps. and input stage in Figs. 5 and 3.

resistors become a minor adjustment to the audio feedback network. The op. amps. shown in *Fig. 4* have the circuit of *Fig. 5*.

The layout does not appear to be critical: in the trial equipment the signal network is mounted between the tags on the potentiometers and tags on a tag strip: the amplifier sections are built on Radiospares miniature 18-way group boards. The bias resistors marked $1.41\text{M}\Omega *$ in *Fig. 5* are each made up of three resistors in series the values being selected on trial to give a d.c. level of $6\,\text{V} \pm 0.2\,\text{V}$ at the output point with a supply voltage of 12, $1.41\text{M}\Omega$ being the calculated value. This method of adjustment is cheap and not seriously time-consuming or inconvenient for the home constructor: otherwise a variable resistor of $1\,\text{M}\Omega$ in series with a fixed resistor of $820\,\text{k}\Omega$ or $1\,\text{M}\Omega$ could be used. Half-watt moulded carbon resistors have been used throughout, with no apparent disadvantages.

Power is obtained from a small commercial stabilized supply unit: this is not strictly essential provided there is good smoothing, but it is a very convenient way of providing the smoothing and obtaining the correct operating voltage.

The tone balance control performs satisfactorily the function for which it was intended and which cannot be performed by the normal Baxandall bass and treble controls. It compensates quite accurately (judging by ear) for some of the variations in recording characteristics used in the early days of l.p. records and for similar sounding, probably fortuitous, variations in some more recent records: it even enables reasonably well-balanced results to be obtained from a variety of 78 r.p.m. records reproduced through the current standard l.p. playback, characteristic, with some help from the normal treble control. It compensates satisfactorily most (but not all) of the "off-balance" radio programmes mentioned earlier.

The approximate equality of maximum bass boost or cut and treble cut or boost, together with the choice of 800-880Hz for the centre frequency, ensures that the general volume level remains reasonably constant when the tone balance control is adjusted. The frequency of 800Hz is a reasonable compromise between the geometric mean of the audio spectrum (630Hz), the nominal bass-to-middle crossover of the writer's speaker system (750Hz), the nominal bass boost hinge frequency of commercial records (500Hz) and the nominal treble cut hinge frequency of records (2kHz).

The tone balance control has been found to have additional uses. On the writer's equipment its normal setting is one giving a little bass boost and treble cut, to compensate for a slightly lower sensitivity in the bass speaker compared with the middle speaker. The control also seems able to provide a useful single-knob tone control in moderate quality systems of slightly restricted frequency range, simulated on a wide-range system by the application of some bass cut and treble cut with the normal Baxandall controls.

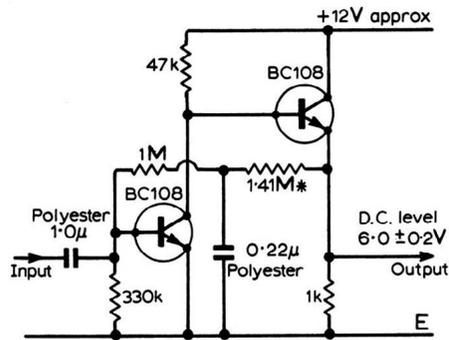It is not suggested that the tone balance control supersedes the Baxandall circuit in

Fig. 5. Circuit of each op. amp. in Fig. 4. Resistor marked "1.41M*" to be adjusted on trial—see text.

high-fidelity equipment; it has a different function. In fact the best results and the widest range of control and compensation are obtained by providing both the Baxandall type of control and the new one. If this is done there is some advantage in adjusting the characteristics of the Baxandall system to leave a slightly wider "flat" gap than would normally be provided between the bass and treble characteristics. It would also seem desirable to provide both low-pass and high-pass variable filters but the writer has not yet done this.

REFERENCES

1. D. T. N. Williamson, "Design of Tone Controls and Auxiliary Gramophone Circuits," *Wireless World*, October, November 1949.
2. P. J. Baxandall, "Negative-Feedback Tone Control," *Wireless World*, October 1952.
3. A. R. Bailey, "High Performance Transistor Amplifier" (Control Unit), *Wireless World*, December 1966.
4. D. T. N. Williamson, "Design for a High-Quality Amplifier," *Wireless World*, May 1947, August 1949.
5. J. L. Linsley Hood, "Simple Class A Amplifier," *Wireless World*, April 1969.

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But in the the QUAD 34, 44, 66 it did replace the Baxandall circuit tone controls with only ±3dB of lift and cut at each end of the audio range see:- http://www.keith-snook.info/QUAD-34-mods.html