interference current may flow in this earthing lead, which, with normal constructional arrangements, would be taken to earth somewhere well inside the amplifier enclosure. An RF magnetic field is thus created which causes interference voltages to be induced into the rest of the circuitry – an effect which good designs always aim to minimize.

The general experience seems to be that it is normally better not to earth the centre-tap but to leave the primary winding floating, and this is now the nearly universal practice. Occasionally a switch has been provided so that a centre-tap may be used as an optional alternative – it is sometimes the better choice if the main interference is at high audio frequencies owing to a leaky cable screen.

With the centre-tap omitted, some interference current, usually of much smaller magnitude, will flow to earth via the transformer capacitances, and it used to be almost universal practice to include an earthed electrostatic screen between the transformer windings to prevent this current reaching the secondary winding. However, because of the low secondary impedances made possible by the advent of transistors, it is found that entirely satisfactory results can usually be obtained without involving the extra cost of a screen – many BBC microphone transformers have no screen, for example.

The low impedance allows a sizable capacitor, e.g. 1 nF, to be connected across the secondary circuit, and this capacitor can be put extremely close to the input transistor for effective VHF interference suppression. Sometimes a series inductor may be added for further filtering action. (The connection of such a capacitor directly between base and emitter of an input stage is a somewhat questionable technique, since it can cause oscillation by creating a negative input conductance.)

An overriding consideration is that the outer screen of a microphone cable should be taken solidly to earth right at the input socket and not via a lead wandering around near the amplifier circuitry.

8.5.16 Transformers and negative feedback

The benefits of negative feedback may be applied to microphone transformers, high-level line-input transformers, and output transformers.

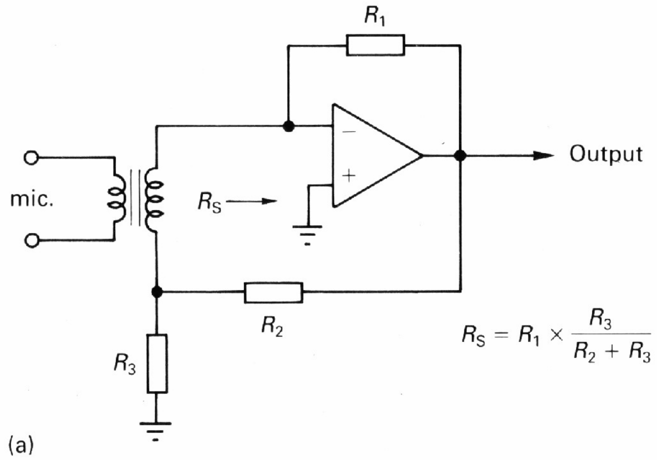
Figure 8.35 shows two ways in which a desired value of secondary loading resistance, R_S, (see Section 8.5.4) may be produced without introducing significant degradation of the noise figure. The (a) scheme is that used in the BBC microphone amplifier circuit of Figure 8.6.

The formula given for the (b) scheme is a general one, equally relevant in other contexts where the circuit may be used to produce negative resistance. For the present application, A is made negative, say –100.

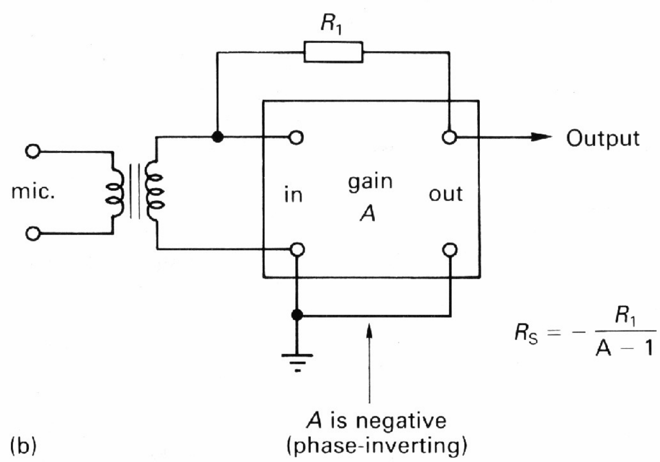
Figure 8.36 shows, slightly simplified by the omission of small capacitors across the op. amp. resistors, a circuit designed for KEF Electronics Ltd for use in a studio monitor loudspeaker with self-contained amplifiers. The aim is to provide a high-impedance floating input, suitable for bridging across any available signal line, and giving a high degree of rejection of common-mode interference present on the line.

The transformer is wound highly symmetrically on a two-section bobbin, with the half-secondaries, wound in reverse directions, at the inner radius for minimum resistance – the primary resistance is of no importance whatever, and thinner wire was in fact used for this winding. The primary and secondary are well spaced apart by low-loss insulation, giving an inter-winding capacitance of less than 30 pF.

To maintain overall symmetry of behaviour, the amplifier that follows the transformer is also balanced, both inputs being virtual earths – or virtual grounds if this term is preferred!



(a)



(b)

Figure 8.35 *Circuits giving effective secondary loading of value R_S, with negligible sacrifice of signal-to-noise ratio.*

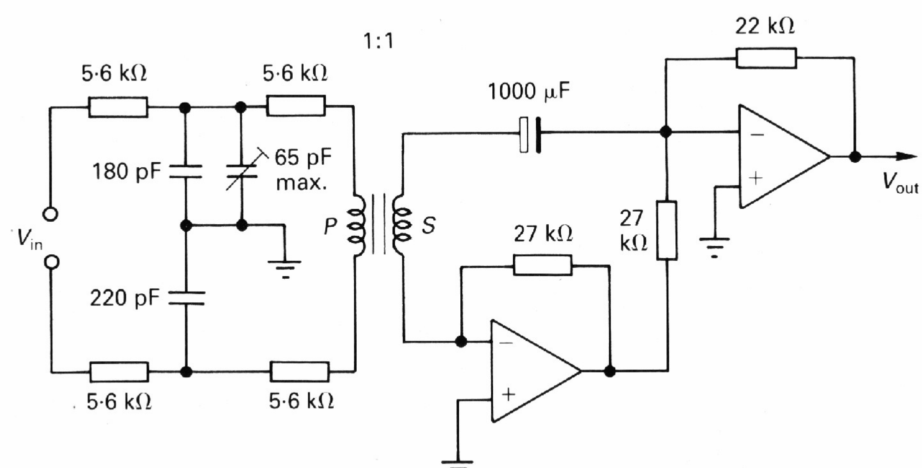


Figure 8.36 *Balanced input circuit for active studio monitoring loudspeaker.*

Feeding a transformer in this way to an almost zero impedance is enormously beneficial with regard to frequency response and distortion, since the core hardly has to develop any flux density at all.

The distortion for an input level of 0.775 V r.m.s. at 30 Hz, both as predicted using the universal curve of Figure 8.31 and as directly measured, is well under 0.001%.

The frequency response is flat within ±1 dB from 2 Hz to 100 kHz, and immaculately flat over the whole audio band. There is a peak of about 5 dB at 0.8 Hz owing to series resonance between the secondary inductance and the 1000 μF capacitor, but this may be eliminated, if desired, by replacing this capacitor by a network involving two capacitors and a resistor.

The noise level relative to 0.775 V is −108 dBA, and the unweighted hum level is also about −108 dB even with the screened input transformer about 20 cm from a large mains transformer.

With the trimmer capacitor correctly set, the common-mode rejection ratio is better than 90 dB at 1 kHz and better than 70 dB at 10 kHz.

The transformer used in the version of the scheme described above is wound on a Mumetal core of the same size as for the microphone transformer of Section 8.5.2, and has 1000 turns on both primary and secondary. A more economical version, using a ferrite transformer core, is used by Quad Electroacoustics Ltd for a professional amplifier input stage.

Reducing the shunt inductance to a fairly low value has no adverse effect on the audio frequency response, though it gives an increase in low-frequency noise, which nevertheless still remains inaudible.

A different embodiment of the same broad principle, evolved quite independently, is described in Reference 34, and employs only a single op. amp. The secondary winding feeds the inverting input of this, but the feedback resistor, instead of being taken to this input, is taken to a tertiary winding. Assuming infinite op. amp. gain, this scheme ideally reduces the flux density right down to zero, which allows an extremely small transformer to give a very good performance.

An alternative way to achieve the above result, which I tried at the time the Figure 8.36 circuit was evolved, but found it unnecessary to adopt, is to apply a little positive feedback to one of the op. amps., making it into an open-circuit-stable negative resistance (see below) of magnitude equal to the secondary copper resistance of the transformer.

Transformers are often used to provide a high-level floating line output for feeding to other equipment. Because of the use of negative feedback, the output impedance is usually very low, but in self-contained studio installations the loading imposed on such an output is normally quite light. Line output voltage levels are usually expressed in dBu, i.e. decibels relative to 0.775 V r.m.s. – see footnote near the end of Section 8.3.11. Sometimes, however, such as in outside broadcast equipment, which has to feed into a long telephone line, the requirement is for a purely resistive output impedance of specific value, such as 75 Ω.

With early transistor equipment,[17,18] push–pull PNP output stages, with a centre-tapped transformer primary, were normally used, the negative feedback being preferably derived from a tertiary winding.[35,36]

The later availability of complementary transistors, and more particularly of suitable op. amps., has enabled such transformers to be driven in a 'single-ended' manner, the simplest such arrangement being that of Figure 8.37.

The distortion in the voltage across the primary is made very low by the negative feedback, but the secondary voltage will contain a small amount of distortion owing to the flow of the highly distorted magnetizing current in the

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