plus undetermined amounts of higher harmonics which, judging from the sharpness of the bend in Fig. 7 and the magnitude of the 7th harmonic, are likely to be very significant aurally if not numerically. It is true that the total harmonic distortion, found by taking the square root of the sum of the squares of the above lot, is only 15.6% But if anyone thinks this is an improvement on the 20% without feedback he oughtn't to be let out alone in the hif-fi market. He would be an easy prey to the merchants, whose motive in quoting t.h.d. figures is only too clear to those who have compared actual sound reproduction with the harmonics present. Though opinions of authorities differ as to the factors by which harmonics higher than the second should be multiplied to give some idea of their relative unpleasantness, the most conservative suggest (without necessarily admitting that it is adequate) a weighting factor equal to half the harmonic order. For instance, the 0.83% 7th harmonic would have to be multiplied by 3½, raising it to 2.9%. D. E. L. Shorter of the BBC considered the square of this factor not excessive. That would raise the 7th-harmonic figure for comparison with the second to over 10%.

At this point a red herring labelled 'intermodulation' is almost certain to be seen crossing our path. But if any benefit is to be derived from the time you have so self-sacrificingly spent in following me thus far, I advise that we refrain from spending any more in chasing after it. No doubt we know that the products of intermodulation, being in general not musically related to the tones present in the original sounds, are more objectionable than at least the lower harmonics, which are; but it doesn't follow that one must insist on intermodulation data and refuse harmonics as worthless substitutes. For, when measured under comparable conditions, harmonic percentages are more or less proportional to intermodulation percentages, so can be used as comparative indexes of intermodulation, easier to measure. And anyway, in this case we are getting the higher harmonics, which are discordant in their own right.

Another possible red herring is one that isn't nearly as fresh as it is often made out to be by means of new-fangled terms such as transient intermodulation distortion and slewing-rate distortion. It is in fact many years old, and although it too is an undesirable product of ill-designed negative feedback it also is an avoidable one, not directly related to the present subject.

Getting back to our uneasy contemplation of Fig. 7, we see that there is nothing for it but to reduce the input signal until the sharp bend is cleared; say ±0.25V peak. The output, which by then is nearly all fundamental, is barely 2.5V, or less than 40% of the power we got in Fig. 4, admittedly with lots of second harmonic too. But if we reduce the fundamental without feedback to the same level, the second harmonic comes down to 12½%, which on paper is certainly not hi-fi, but wouldn't greatly offend as many listeners as you might think.

It is now time to sum up:

(1) The common belief that negative feedback reduces non-linearity distortion in the same ratio as it reduces amplification is strictly true only if there is no non-linearity to reduce.

(2) However, provided that the original non-linearity is not so bad that the slope of the output/input curve (which is the amplification) falls seriously below the nominal value at any point within the maximum signal amplitude, the common belief is fair enough.

(3) It follows from (1) and (2) that any idea that one can sling an amplifier together any old how and pull it straight with liberal supplies of negative feedback is unsound — even apart from the practical difficulties of this treatment.

(4) While negative feedback works like a charm on amplifiers with *moderate* non-linearity, run well within their capability, it doesn't necessarily increase the amount of power that can be drawn; on the contrary, it may reduce it.

(5) In any case, once the signal amplitude runs past the nearly-undistorted limits, it abruptly becomes very distorted, not only as regards quantity but even more as regards quality. In other words, even a moderately overloaded amplifier sounds a lot worse with feedback than without.

(6) The fact that hi-fi fans insist, especially in America, on vast numbers of output watts being available, in spite of the surprisingly small *average* power needed for even quite loud reproduction, is thus explained.

(7) The fact that demonstrations of 'hi-fi', unless conducted by masters of the art, are usually such painful experiences, is also explained. The demonstrator so often doesn't reckon that he is doing his job if the output falls below the maximum rating.

Except by dividing signal voltages by 10 in order to be more appropriate for modern transistors than were those in the valve version of 1961, and writing a new introduction on Fig. 1, I have followed much the same lines as in the original and have arrived at the same conclusions. Present readers will no doubt be thinking I ought to have reduced the distortion figures by a factor of at least 10 to be more in accord with present-day amplifiers. But it must be remembered that, with the larger amounts of feedback now used, its effects on overloading can be even worse than are shown here, intentionally exaggerated though they were to get the message across. This has been dramatically confirmed as recently as the July 1978 issue, where on p.57 James Moir showed a curve which clearly illustrates my very point — that distortion without feedback is, at a certain output level, suddenly and vastly overtaken by distortion with feedback.

I hope that, by confining the no-feedback distortion to only one harmonic, I have left no room for the fallacy that all distortion harmonics are necessarily reduced by negative feedback in the same ratio as the gain – or even at all, since we have seen that many harmonics can actually be created by feedback that were not there without it. □

LITERATURE RECEIVED

Video display unit ZIP-64 from Data Dynamics is said to offer low cost with high performance. A leaflet can be had from Data Dynamics at Data House, Springfield Road, Hayes, Middlesex WW412

P.r.o.m. programming equipment made by Data I/O and a large list of p.r.o.m.s from twenty suppliers is presented in a leaflet from Microsystem Services, Duke Street, High Wycombe, Bucks. WW413

Illuminated push switches illustrated and described in 28-page catalogue from Licon, Norway Road, Hilsea Industrial Estate, Portsmouth PO3 5HT WW414

Power supplies and components for use with equipment vulnerable to transients and line regulation and in conditions where supply must not be broken are all described in the Topaz catalogue from Euro Electronic Instruments Ltd, Shirley House, 27 Camden Road, London NW1 1YE .....

Single-board computers in the Intel range of o.e.m. equipment have been summarized by Rapid Recall in a pocket guide obtainable from Rapid Recall at 9 Bell Street, Drury Lane, London ..... W

Turntables from Collaro are updated and described in leaflets from Magnavox Electronics Company Ltd, By-pass Road, Barking, Essex 1G11 0TF WW417

Picoammeter from Keithley, Model 480, is discussed in general and specified in a brochure from Keithley Instruments Ltd, 1 Boulton Road, Reading RG2 0NL . WW418

"DC Motors, Speed Controls, Servo Systems" is the title of a 500-page handbook from Electrocraft. It is available at £3 from Unimatic Engineers Ltd, Granville Road Works, 122 Granville Road, Cricklewood, London NW2 2LN.

Audio kits from Powertran are illustrated, described and priced in a catalogue obtainable from Powertran Electronics, Portway Industrial Estate, Andover, Hants SP10 3NN. WW designs offered include the Linsley Hood cassette deck, Nelson-Jones f.m. tuner, Stuart tape recorder and Linsley Hood audio oscillator WW419