Distortion on & off record

John Linsley Hood describes a simple distortion meter for pickup cartridge alignment

MY MAJOR spare-time interest is in listening to recorded music. Because I am, by occupation, an electronics engineer it is a fairly predictable outcome that I would become interested in having a go at designing my own audio equipment for the reproduction of the collection of gramophone records which I have accumulated over the past 40 years. Apart from the possession of an inquisitive mind, and a willingness to experiment, the two major assets to which a potential audio amplifier designer should have access (apart from the projections on the sides of his head) are an oscilloscope and a distortion meter. The first of these allows him to see whether there is anything grossly amiss, and the second shows him whether he has been successful in eliminating some of the more minor defects.

While it is true that both engineers and critics have begun to doubt whether instruments, alone, are fit to give any piece of audio equipment a clean bill of acoustic health, the converse remains undoubtedly valid. No equipment having any major defect demonstrable by instrumental measurement would not be improved — other things being equal — if that defect were eliminated. So, in spite of the fact that most sensible engineers are aware that there are defects which their instruments may not readily reveal, the scope and the THD meter remain test bench companions, supplemented where possible by other more specialised test gear.

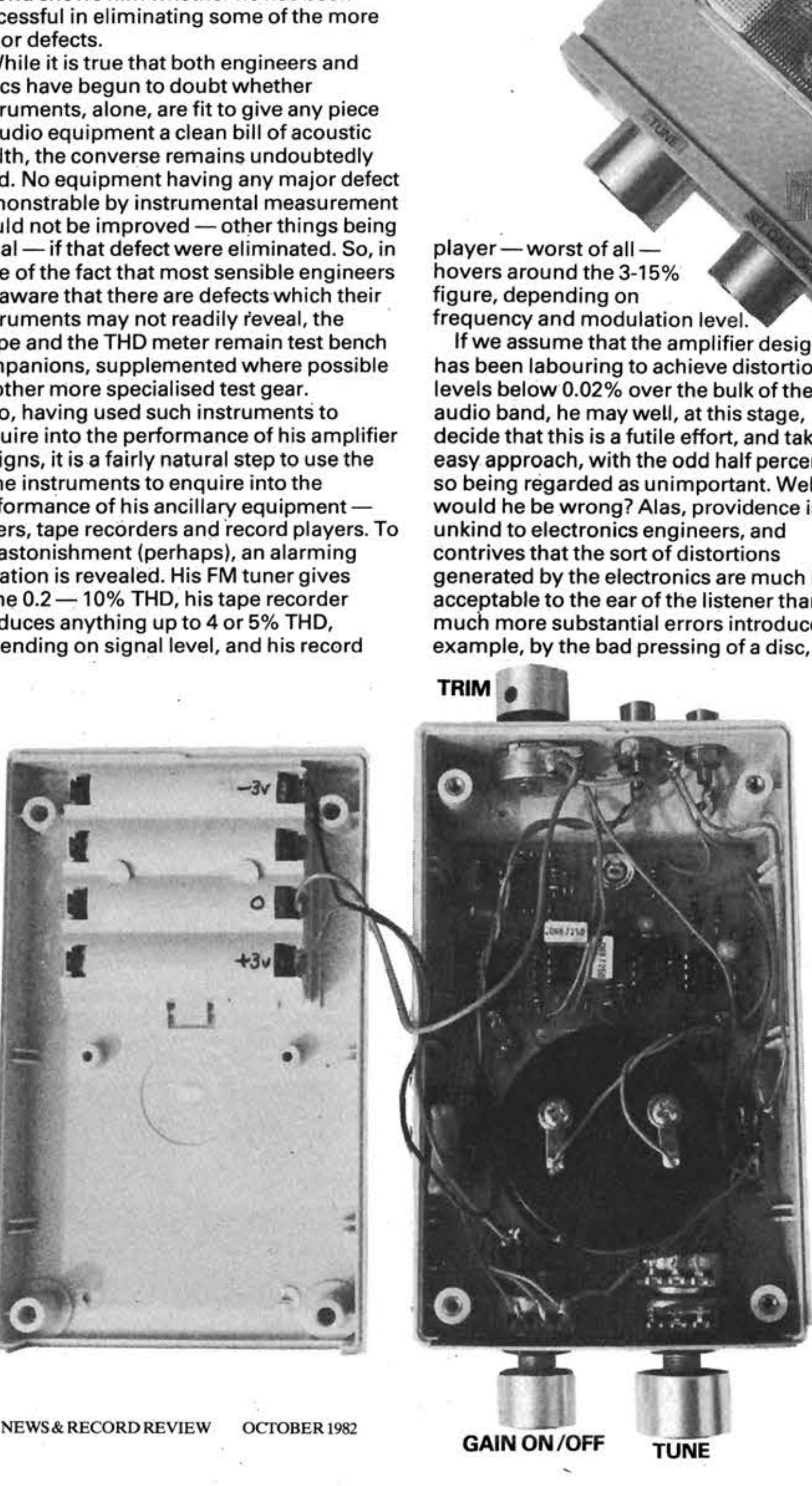
So, having used such instruments to enquire into the performance of his amplifier designs, it is a fairly natural step to use the same instruments to enquire into the performance of his ancillary equipment — tuners, tape recorders and record players. To his astonishment (perhaps), an alarming situation is revealed. His FM tuner gives some 0.2 — 10% THD, his tape recorder produces anything up to 4 or 5% THD, depending on signal level, and his record player — worst of all — hovers around the 3-15% figure, depending on frequency and modulation level.

If we assume that the amplifier designer has been labouring to achieve distortion levels below 0.02% over the bulk of the audio band, he may well, at this stage, decide that this is a futile effort, and take the easy approach, with the odd half percent or so being regarded as unimportant. Well, would he be wrong? Alas, providence is unkind to electronics engineers, and contrives that the sort of distortions generated by the electronics are much less acceptable to the ear of the listener than the much more substantial errors introduced, for example, by the bad pressing of a disc, or by its inadequate tracing by the stylus of the cartridge.

The precise degree of objectionableness of the many possible distortion components is a field in which the psycho-acoustic specialists have uncovered a lot of interesting data, not least of which is that different listeners differ somewhat in their objections. However, in crude terms, it would appear that the 'mechanical' types of distortion — such as those introduced by the inaccurate motions of a stylus or a loudspeaker cone — are more tolerable psycho-acoustically than the more unfamiliar waveform mutilations generated by unsatisfactory electrical behaviour.

Nevertheless, the situation remains that developments in the field of audio amplifier design have led to these being offered, not necessarily only at the top end of the market, with THD figures well below 0.01% over much of the power, and frequency, spectrum. There have been relatively small improvements during this period in the equipment available for reproducing discs — if only because there is so much less scope for change — and such small improvements as there have been are all too easily masked by small inaccuracies in setting up the cartridge or arm.

For an electronic engineer with access to appropriate test equipment, it is possible, for example, to optimise the adjustments in arm and cartridge geometry, so that an initial replay THD level, from a standard 1kHz, 5cm/s test disc, of 8%+ is reduced to something better than 1% THD under the same conditions. Unfortunately it is not possible to do the same job with an alignment protractor, no matter how well made, simply because it cannot be guaranteed that the major axis of the ellipse of the stylus is correctly aligned in its setting in the cantilever, nor that the rake of the stylus is established with adequate accuracy. After all, the stylus is a very small item, and a 5μ error is very hard to see, even under a microscope. This same error, unfortunately, can make nonsense of the most precise and careful adjustments by the user, when he



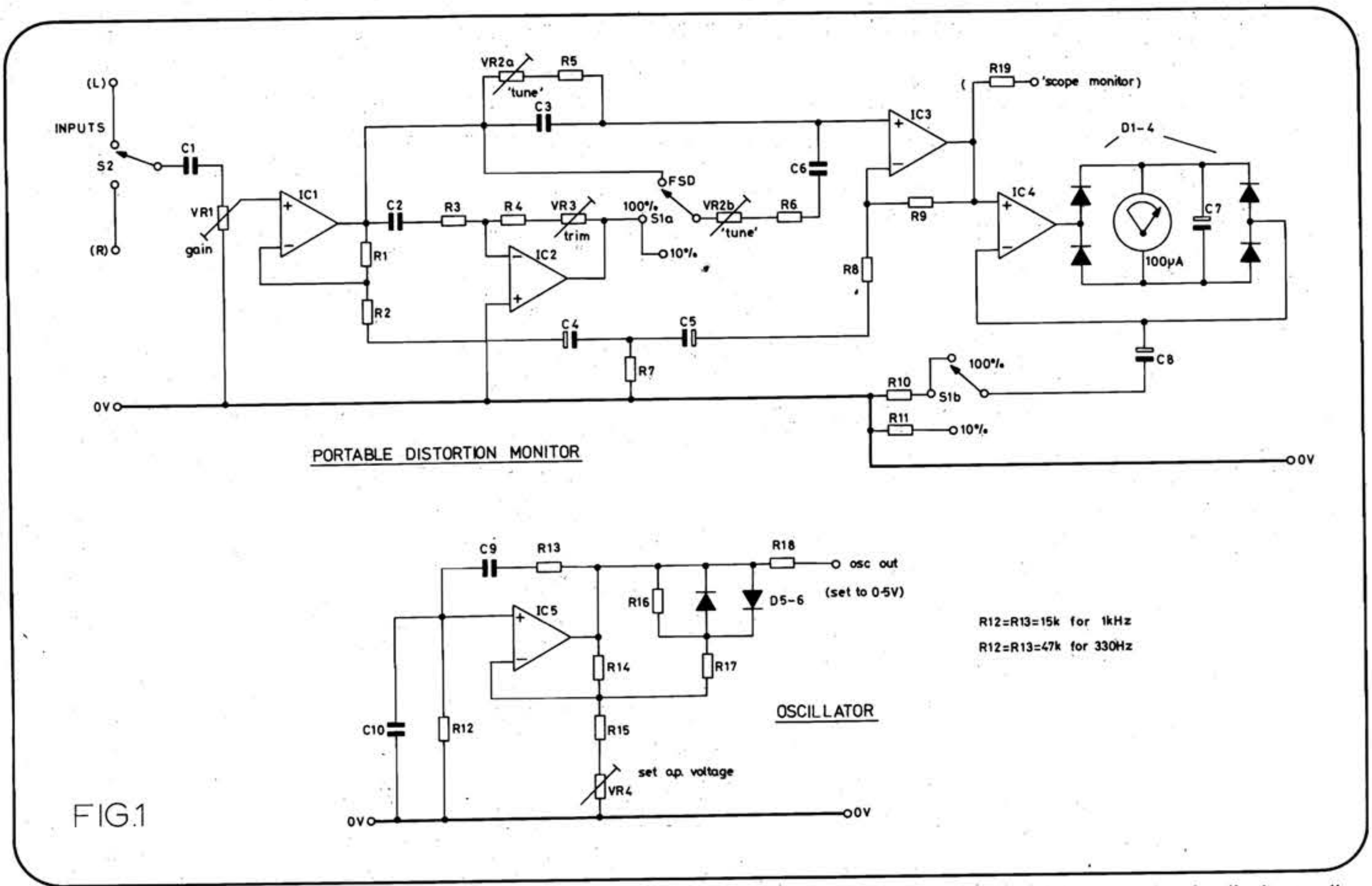


FIG.1

assumes that stylus orientation is indeed correct with respect to the stylus body.

Since this is the case, obviously the answer is to use a test disc and a THD meter, and do the job that way. Test discs are fairly easy to come by. Simple distortion meters, capable of reading down to about 0.5%, unfortunately are not. So, initially, simply to save me the chore of lugging several lumps of equipment backwards and forwards between my laboratory and my living room every time I substituted a cartridge or upgraded an arm, and subsequently (in a tidied up version) as a contribution to the facilities offered by one of the more concerned of my local dealers, I evolved the present design.

Having done this work, and having benefited by it in setting up my own three domestic cartridges so that they now give the sort of replay distortion figures the designers had in mind (in every case, the THD improvement was better than two-fold, and in the case of the best of the cartridges, with the least well aligned stylus, the improvement was sevenfold — and very noticeable!) it seemed a pity not to spread the idea around a bit further.

The design of the instrument

The basic intention of this design was to make a small, cheap, and easily portable unit which could be plugged into the LS output or headphone sockets of an audio amplifier, and which would allow a THD reading to be displayed, by a suitable meter, on an instrument which could be battery operated, capable of measuring down to, say, 0.2% THD. Since previous measurements with much more complex and sensitive measuring gear had shown that even the best of the PU cartridges in my possession would not better 0.8% THD, it did not seem worthwhile to attempt a threshold sensitivity a lot better than 0.2%.

Having contemplated the possible uses of such an instrument, it also seemed a good idea to include within the package a simple fixed frequency sinewave oscillator, of, say, 0.1% distortion or better, which would allow the distortion meter also to be used for setting up bias and recording levels with tape or cassette recorders. If these recorders are of the 'three-head' variety so that the measurement can be made while the tape is passing through the machine ('in real time' as the computer jargon has it), this measurement becomes very simple, and can allow the user to determine just how much leeway he has, around the 'O VU' level, before the THD becomes objectionable, for any given tape, in a matter of a minute or so.

The instrument case which I had in mind to accommodate this unit was a Verocase box, having an internal battery compartment which accommodates four HP-7 type batteries. This required a circuit design which would be economical in current consumption, and would work from either 6V or ±3V. The 741 type op-amp. would fit this requirement very nicely, and only takes about 1mA per unit, at this sort of voltage.

Given this decision, the circuit design became fairly straightforward, and is shown in fig.1.

The actual distortion measurement, in an instrument of this type, is made by using an AC millivoltmeter to give a '100%' reading, at some convenient signal level, set by an input 'sensitivity' control. Having set this level to read '100%', the fundamental of the input sinewave signal is then removed by a 'notch' filter and what is left (ie, all components of the signal which are not at the fundamental frequency, which will include any noise and mains 'hum' as well as the distortion components) is then displayed on the meter.

If one aims to look down to 0.2%, this would be an inconveniently small reading on a meter whose full scale setting was 100%, so it is useful to organise the display to allow a 0-10% reading for this purpose, though it is still helpful to allow the distortion to be shown on the 0-100% range to facilitate setting up.

Although there are many 'notch' circuits which can be used for this purpose, the simplest one is the 'Wien' network, in which a variable resistance in series with a fixed capacitor is compared, in impedance, with a similar resistance in parallel with the capacitor. These two variable resistances can be the two halves of a twin-gang potentiometer, which will then allow a single knob adjustment of notch frequency.

The way I have organised this in fig.1 is to feed the 'parallel' network (built up from C6, R6 and VR2b) with the same signal in phase opposition, by the interposition of a phase inverting amplifier stage (IC2). Since the signal fed to the 'series' network requires to be twice the size of that fed to the 'parallel' one, this amplifier is adjusted to give a gain of x2.

One of the problems in the use of a Wien network to generate a 'notch' is that the notch isn't very sharp, and it will also attenuate 2nd and 3rd harmonics of the signal, which is not very satisfactory. However, it is possible to sharpen it up, so that it will completely remove the fundamental frequency while still having 100% transmission at 2nd harmonic and higher frequencies. This I have done by arranging a little negative feedback around the loop from the output of the output amplifier (IC3) to the inverting input of the input buffer stage (IC1). The extent of the sharpening up of the notch is controlled by the resistor (R7). Too high a value here (too much feedback) would make the notch adjustment very difficult to zero, whereas too little might not allow a good reading of the second harmonic residues.

IC4 is the millivoltmeter amplifier, and drives a 100μA (FSD) meter via a ring of small silicon diodes (D1-D4). The switch S1a controls the full-scale or 'notched' reading, while S1b gives the choice of 100% and 10% full scale meter readings. Since it is very useful to be able to make a quick comparison between the performance of the 'left' and 'right' channels, two input leads are provided, selected by switch S2.

To round off the unit, a simple Wien bridge oscillator is provided using IC5. This is stabilised by a pair of diodes, and will give a sinewave output, with the component values shown, at 1kHz, with a distortion of less than 0.15% if the output voltage from the oscillator is set to 500mV RMS, by the adjustment trimmer potentiometer VR4. (R12 and R13 can be changed from 15k to 47k to give a 330Hz output). With a bit of ingenuity, the distortion monitor can be used both as the millivoltmeter to set the output voltage, and also as the distortion measuring instrument to check that the oscillator THD is adequately low. (In this context, the THD will worsen fairly rapidly if the oscillator output is too high).

A double pole battery switch (S3) is necessary to switch both the +3v and the −3v supply lines from the batteries.

Operation

As indicated in the preamble, my original idea was to provide a simple portable unit which would facilitate the proper setting of a cartridge in its head shell, and to adjust, for best performance, the bias and arm height settings. My tests were done using a Thorens TD 160 Super turntable, fitted with a Rega arm, which takes SME type headshells. The test record I prefer, although now unfortunately deleted, is *HFS 69,* which gives steady tone bands at 300Hz, 1kHz and 3kHz, amongst other things. The 1kHz and 3kHz bands are recorded at 5cm/s groove velocity, and lie at approximately ¼ and ⅔rds of the way across the disc, which allows a good assessment of the final tracking alignment.

Strictly, one needs a suitable tone recorded at the two geometric zero points, say, at 66 and 121mm radius. Single-sided test pressings are ideal, as they often have a continuous 1kHz modulation on the other side, but Howland West's *HFS 81* has a suitable 66mm track on side 1. To carry out the test, the test disc is cleaned as thoroughly as practicable and the required test tone played. The THD meter should then be set to give a full scale reading with the switch in the 'FSD' calibration position, by the use of the amplifier gain control and/or the meter gain setting, as appropriate. The stylus is then returned to the start of the test track, to give the longest measurement time possible, and the 'Tune' and 'Trim' controls adjusted to give the best null reading possible. Once an appropriate position has been found for the setting of the 'Trim' potentiometer, it should not be necessary to readjust this to cover any small changes in frequency, though a large adjustment in operating frequency may require that the 'Trim' control be reset — depending on the accuracy of matching of two halves of the 10k ganged 'Tune' pot.

Initial results from this test are likely to appear very poor indeed, with THD readings in the range 5-10% being not uncommon, and fluctuating due to the effects of 'wow', and dust in the grooves. Repeated cleaning may help the latter, and, for myself, I would generally wet the groove with a little distilled water to lessen replay noise. A dampened Dust Bug may also be helpful. Having got some readings, a comparison between L and R channels will allow an optimisation of the 'bias (sidethrust compensation) setting, to give some degree of equality in performance between channels. My own findings are, in general, that a 'bias' setting can be found which will give a large improvement on one channel without too much worsening of the other. It is very rare indeed, in my experience, that both channels are identical 'first time off'.

From this point on, it is simply a matter of rather tedious and repetitive measurements, with the angular and longitudinal position of the cartridge in the head shell, and the horizontality of the cartridge with respect to the record surface, being adjusted, little by little, until it is clear that no further benefit can be gained, and the best compromise between edge and middle of the disc, at the recommended radii, has been reached.

Having optimised my own three cartridges, with the final THD figures, for 1kHz and 3kHz, and on which I have reported in full, I decided that it would be a good idea to extend the scope of this investigation a bit more widely, to include some further interesting PU units, and a further 9 cartridges have been added to the list, through the kind assistance of the *HFN/RR* Editorial office and Shure Electronics Ltd. I have listed the final THD figures arrived at with the help of the Distortion monitor, with oscillograms to show the waveform shape.

In the case of the low output moving-coil cartridges, the necessary preamplification was provided by my own 'Current Transfer' type headamp. This has a total harmonic distortion content which would be less than 0.01% at the typical output voltage levels of normal m-c cartridges, so that any performance degradation due to this cause may safely be neglected.

Tape recorder checking

This is a very much simpler business. In the case of a '3-head' machine, all that is necessary is to inject the 1kHz tone from the test oscillator into the 'Record' input, set the meter FSD on the replayed signal, and read off the THD with the instrument adjusted to give the best null reading. This measurement can then be repeated, for differing 'VU' record levels, with adjustment of the FSD setting as appropriate, and for different tape types.

The HF 'bias' level, if adjustable, will also be found to have a substantial effect on the tape replay distortion level, but one has a more limited freedom to adjust this because of the influence which HF 'bias' has on the flatness of the overall frequency response. (Increasing the bias tends to lower THD but also roll off HF response).

In the case of the simpler 2-head recorder, this business is more laborious, and it is suggested that a series of signals should be recorded — of at least one minute duration at each level — with the tape counter reading being noted at each step, so that on replay it is possible to be sure which is which, and that there is adequate time to reset the FSD on each new burst of signal.

Cartridge test results

Extending the scope of this to include other cartridges from the *HFN/RR* review collection produced some slightly surprising results. As I have mentioned, my original interest in this project arose from the decision to optimise my cartridge geometry

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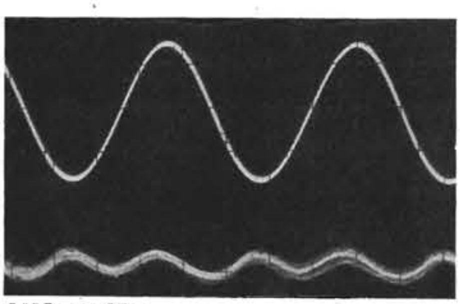

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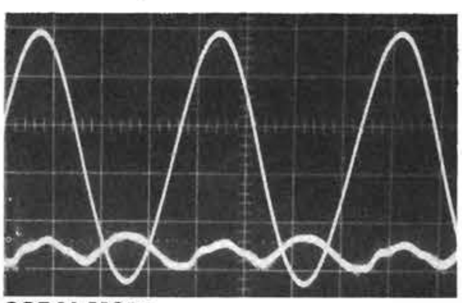

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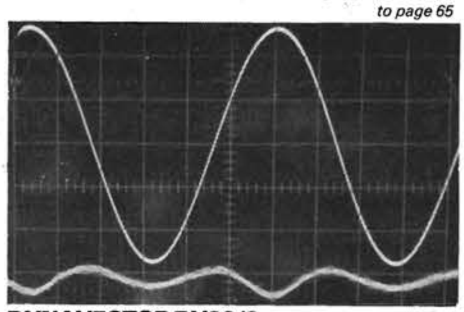

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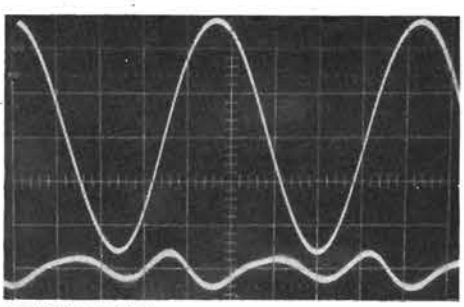

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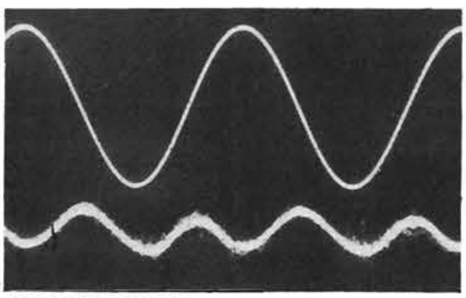
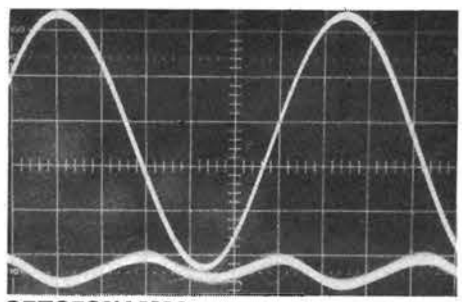


ORTOFON MC20



ORTOFON LM30