Science and Subjectivism in Audio.

In the last twenty years, there has developed a major dislocation between the scientific evaluation of audio equipment and "subjective" assessment, the latter philosophy having come to be called "Subjectivism"....

This is an expanded version of an article that appeared in the UK journal *Wireless World* for July 1988.

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Much more detail on distortion and other matters can be found in the book I finally got round to writing:

Book

Last updated: 9 Aug 1998

GENERAL AUDIO AND PSEUDOSCIENCE LINKS.

- **ABX Double-Blind Comparator & Results.**
- **The DIY Audio Pages.** **Many, many links.**
- **Audioweb.** **Comprehensive.**
- **James Randi Site.** **A rationalist and a hero.**

1: SCIENCE AND SUBJECTIVISM.

Audio engineering is in a singular position. There can be few branches of engineering science rent from top to bottom by such a fundamental disagreement as the Subjectivist/rationalist dichotomy. Subjectivism is still a significant issue in the hifi section of the industry, but has made little headway in professional audio, where intimate acquaintance with the original sound, and the pressing need to earn a living

with reliable and affordable equipment, provide effective barriers against most irrational flights of fashion. (Note that the opposite of Subjectivist is not "Objectivist". I understand this term refers to the followers- if any- of the philosophies of Ayn Rand)

Most technologies have universally accepted measures of performance car makers compete to improve MPH and MPG; computer manufacturers boast of MIPs (millions of instructions per second) and so on. Improvement in these parameters is universally accepted as progress. In the field of hifi, many people seem to have difficulty in deciding which direction forward is.

Working as a professional audio designer, I often encounter opinions which, while an integral part of the Subjectivist offshoot of hifi, are treated with ridicule by practitioners of other branches of electrical engineering. The would-be designer is not likely to be encouraged by being told that audio is not far removed from witchcraft, and that no-one truly knows what they are doing. I have been told by a Subjectivist that the operation of the human ear is so complex that its interaction with measurable parameters lies forever beyond human comprehension. I hope this is an extreme position for it was proffered as a flat statement rather a basis for discussion.

I have studied audio design from the viewpoints of electronic design, psychoacoustics, and my own humble efforts at musical creativity. I have found complete scepticism towards Subjectivism to be the only tenable position. Nonetheless, if hitherto unsuspected dimensions of audio quality are ever shown to exist, then I look forward keenly to exploiting them. No doubt that most of the esoteric opinions are held in complete sincerity.

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2: THE SUBJECTIVIST POSITION.

A short definition of the Subjectivist position on power amplifiers might read as follows:

- **Objective measurements of an amplifier's performance are unimportant compared with the subjective impressions received in informal listening tests. Should the two contradict the objective results may be dismissed out of hand.**
- **Degradation effects exist in amplifiers that are unknown to engineering science, and are not revealed by the usual measurements.**
- **Considerable latitude may be used in suggesting hypothetical mechanisms of audio impairment, such as mysterious capacitor shortcomings and subtle cable defects, without reference to the plausibility of the concept, or gathering any evidence to support it .**

I believe this is a reasonable statement of the situation. Meanwhile the

overwhelming majority of the public buy conventional hifi systems, ignoring the expensive and esoteric high-end sector where the debate is fiercest.

It may appear unique that a sizable part of a technical industry has set off in a direction that is quite counter to the facts; it might be felt that such a loss of direction in a scientific subject would be unprecedented. This is not so.

Parallel events that suggest themselves include the destruction of the study of genetics under Lysenko in the USSR. [1] Another possibility is the study of parapsychology, now in deep trouble because after some 100 years of investigation it has not uncovered the ghost of a repeatable phenomenon. [2] This sounds all too familiar. It could be argued that parapsychology is a poor analogy because most people would accept that there was nothing there to study in the first place, whereas nobody would assert that objective measurements and subjective sound quality have no correlation at all; one need only pick up the telephone to remind oneself what a 4kHz bandwidth and 10% or so THD sounds like.

A startlingly close parallel in the history of science is the almost-forgotten affair of Blondlot and the N- rays. [3] In 1903, Rene Blondlot, a respected French physicist, claimed to have discovered a new form of radiation he called "N- rays". This was shortly after the discovery of X-rays by Roentgen, so rays were in the air, as it were, and so was a desire to keep up with the Germans. The N-radiation was apparently mysteriously refracted by aluminium prisms; but the crucial factor was that its presence could only be shown by subjective assessment of the brightness of an electric arc allegedly affected by N-rays. No objective measurement appeared to be possible. To Blondlot, and at least fourteen of his professional colleagues, the subtle changes in brightness were real, and the French Academy published more than a hundred papers on the subject.

Unfortunately N-rays were completely imaginary, a classic product of the "experimenter-expectancy" effect. This was demonstrated by American scientist Robert Wood, who quietly pocketed the aluminium prism during a demonstration, without affecting Bondlot's recital of the results. This was widely reported by the famous reporter/explorer William Seabrook, and the N-ray industry collapsed very quickly. It was a major embarrassment at the time, but is now almost forgotten.

This demonstrates that it is quite possible for large numbers of sincere people to deceive themselves when trying to perform subjective assessments of phenomena.

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3: A BRIEF HISTORY OF SUBJECTIVISM.

The early history of sound reproduction is notable for the number of times that observers reported that an acoustic gramophone gave results indistinguishable from reality. Such such statements throw light on how powerfully mind-set affects

subjective impressions. When interest in sound reproduction grew in the post-war period, technical standards such as DIN 45-500 were set, though they were soon criticized as too permissive. By the late 1960s it was almost universally accepted that the hi-fi requirements would be met by: "THD less than 0.1%, with no significant crossover distortion, frequency response 20-20kHz, and as little noise as possible, please". The early 1970s expanded this to include slew-rates and properly behaved overload protection, but the approach was always scientific and it was perfectly normal to read amplifier reviews in which measurements were dissected but no mention made of listening tests.

Following the growth of subjectivism through the pages of one of the leading Subjectivist magazines (HiFi News), the first intimation of things to come was the commencement of Paul Messenger's column "Subjective Sounds" in September 1976. He said "The assessment will be (almost) purely subjective, which has both strengths and weaknesses, as the inclusion of laboratory data would involve too much time and space, and although the ear may be the most fallible, it is also the most sensitive evaluation instrument". Subjectivism as an expedient rather than a policy. Significantly, none of the early instalments contained any references to amplifier sound.

In March 1977, an article by Jean Hiraga was published attacking high levels of negative feedback and praising the sound of an amplifier with 2% THD. In the same issue, Paul Messenger stated that a Radford valve amplifier sounded better than a transistor one, and by the end of the year the amplifier-sound bandwagon was rolling. Hiraga returned in August 1977 with a highly contentious set of claims about audible speaker cables, and after that no hypothesis was too unlikely to receive attention.

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4: THE LIMITS OF PERCEPTION.

In evaluating the Subjectivist position, it is essential to consider the known abilities of the human ear. Contrary to the impression given by some commentators, who call constantly for more psychoacoustical research, an enormous amount of hard scientific information already exists on this subject, and some of it may be briefly summarized thus:

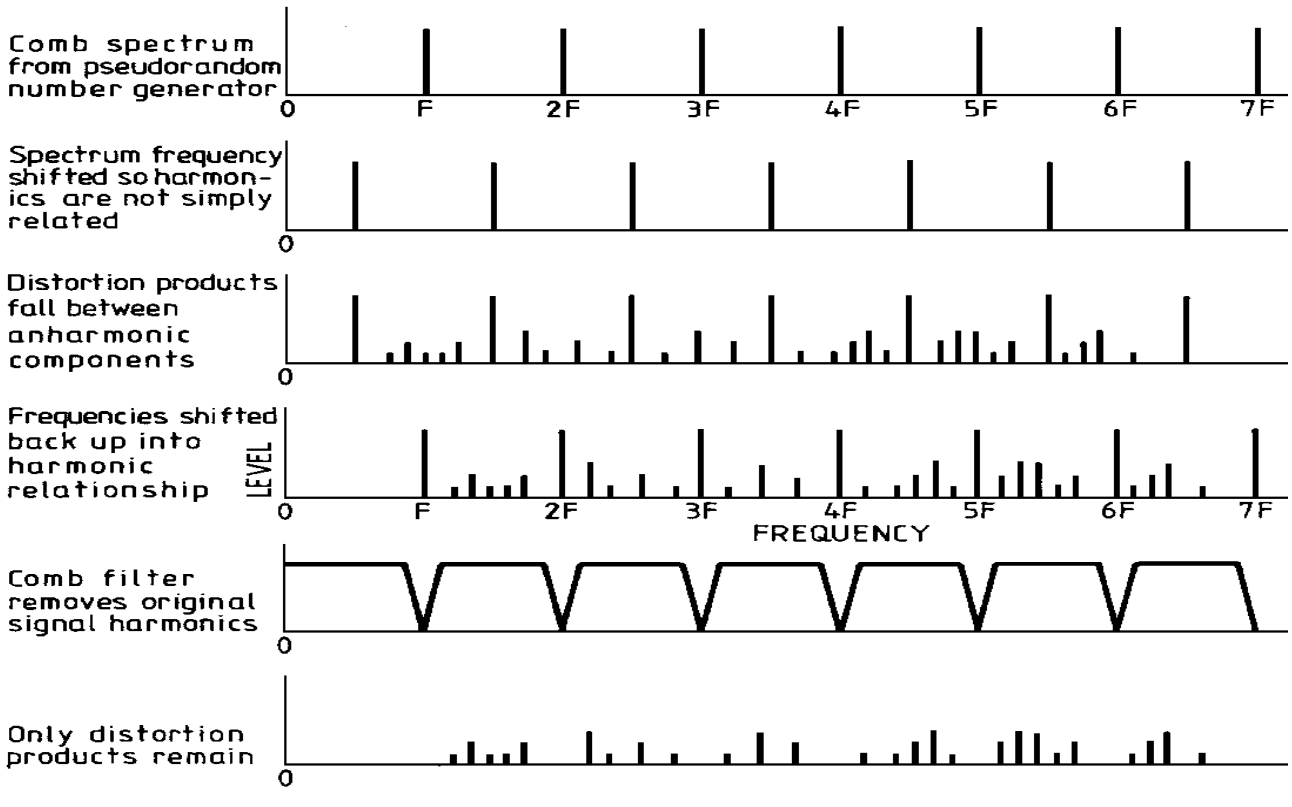
The smallest step-change in amplitude that can be detected is about 0.3dB for a pure tone. In more realistic situations it is 0.5 to 1.0dB'". This is about a 10% change. [4]

The smallest detectable change in frequency of a tone is about 0.2% in the band 500Hz-2kHz. In percentage terms, this is the parameter for which the ear is most sensitive. [5]

The least detectable amount of harmonic distortion is not an easy figure to determine. Many variables are involved, and in particular the continuously varying signal levels mean the level of THD generated is also dynamically changing. With mostly low-order harmonics present the just-detectable amount is about 1%,

though crossover-distortion can be perceived at 0.3%, and probably lower. There is certainly no evidence that an amplifier producing 0.001% THD sounds any cleaner than one producing .005% [6]

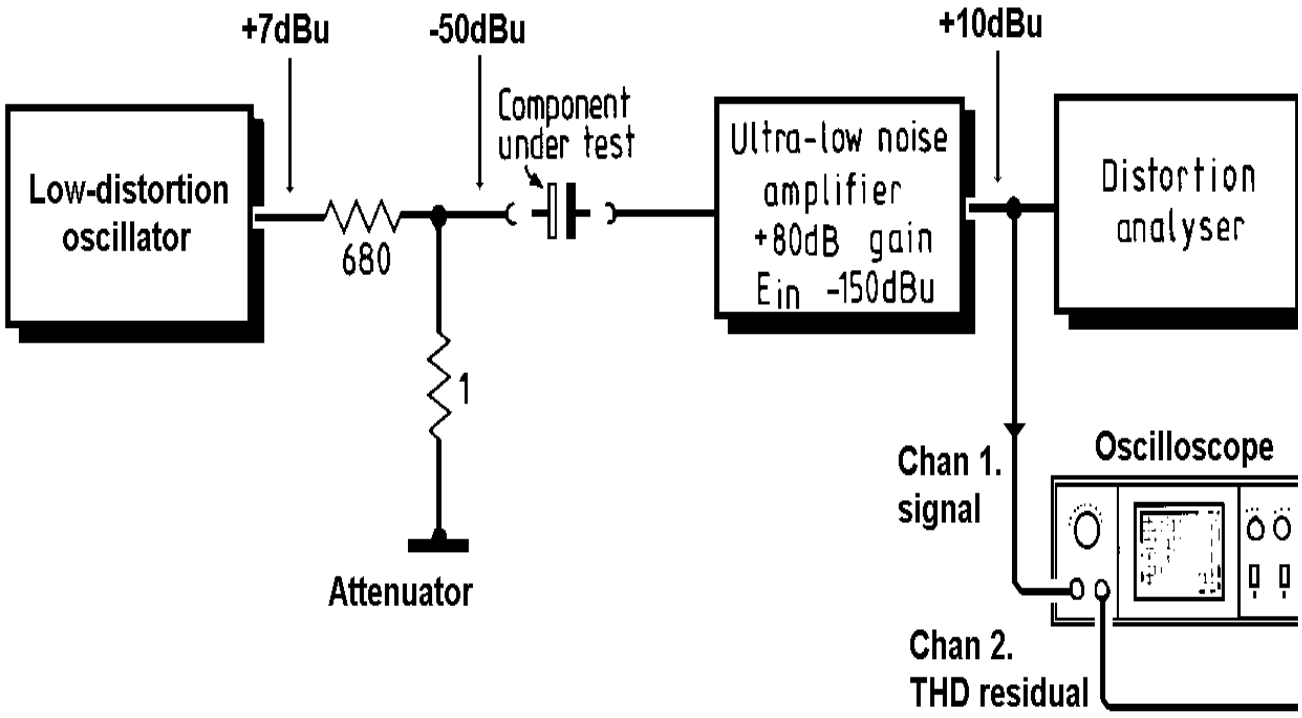
THD measurements, taken with the usual notch-type analyser, are of limited use in predicting the subjective impairment produced by an imperfect audio path. With music etc, intermodulation effects are demonstrably more important than the harmonics themselves. However, THD tests do have the unique advantage that inspection of the distortion residual on an oscilloscope gives an experienced observer immediate insight into the root cause of the non-linearity. Many other distortion tests exist which, though yielding very little information to the designer, exercise the whole audio bandwidth at once and correlate well with properly-conducted tests for subjective impairment by distortion. The Belcher intermodulation test (the principle is shown in Fig 1.1) deserves more attention than it has received. It may become popular now that DSP chips are becoming cheaper and cheaper.



Principle of Belcher intermodulation test. Fig 1.

An objection often made to THD testing is that its resolution does not allow verification that no non-linearities exist at very low level; presumably some sort of micro-crossover distortion. Hawksford, for example, has stated "Low-level threshold phenomena... set bounds upon the ultimate transparency of an audio system" [7] and several writers have claimed that some metallic contacts consist of a net of so-called 'micro-diodes'. Actually, this sort of mischievous hypothesis can be

easily disposed of using enhanced THD techniques. I evolved a method of measuring THD down to 0.01% at 200 microvolts rms, and applied it to large electrolytics, connectors of varying provenance, and lengths of copper cable with and without alleged magic properties. The method required the design of an ultra-low noise (EIN= - 150 dBu for a 10 source resistance) and very low THD. [8] The measurement method is shown in Fig 1.2; using an attenuator with very low resistance values to reduce the incoming signal keeps Johnson noise to a minimum. In no case was any unusual distortion detected, and it would be nice to think that this red herring at least has been laid to rest.



THD measurement at very low levels. Fig2.

Interchannel crosstalk can obviously degrade stereo separation, but the effect is not detectable until it is worse than 20dB, which would be a very bad amplifier indeed. [9]

Phase and group delay have been an area of dispute for a long time. As Stanley Lipshitz *et al* have pointed out, these effects are obviously perceptible if they are gross enough; if an amplifier was so heroically misconceived as to produce the top half of the audio spectrum three hours after the bottom, there would be little room for argument. More practically, concern about phase has centred on loudspeakers and their crossovers, as the only place where a phase-shift might exist without an accompanying frequency-response change to make it obvious. Lipshitz appears to have demonstrated [10] that a second-order all-pass filter (an all-pass filter gives a

frequency-dependant phase-shift without level changes) is audible, whereas BBC findings, reported by Harwood [11] indicate the opposite, and the truth of the matter is still not clear. This controversy is of limited importance to amplifier designers, as it would take truly spectacular incompetence to produce a circuit that included an accidental all-pass filter. Without all-pass filtering, the phase response of an amplifier is completely defined by its frequency response, and vice-versa; in Control Theory this is Bode's Second Law, [12] and it should be much more widely known in the hi-fi world than it is. A properly designed amplifier has its response roll-off points not too far outside the audio band, and these will have accompanying phase-shifts; there is no evidence that these are perceptible. [8]
The picture of the ear that emerges from psychoacoustics and related fields is not that of a precision instrument. Its ultimate sensitivity, directional capabilities and dynamic range are far more impressive than its ability to measure small level changes or detect correlated low-level signals like distortion harmonics. This is unsurprising; from an evolutionary viewpoint the functions of the ear are to warn of approaching danger (sensitivity and direction-finding being paramount) and for speech. In speech perception the identification of formants, (the bands of harmonics from vocal-chord pulse excitation, selectively emphasised by vocal-tract resonances) and vowel/consonant discriminations, are infinitely more important than any hi-fi parameter. Presumably the whole existence of music as a source of pleasure is an accidental side-effect of our remarkable powers of speech perception: how it acts as a direct route to the emotions remains profoundly mysterious.

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5: ARTICLES OF FAITH: THE TENETS OF SUBJECTIVISM.

All of the alleged effects listed below have received considerable affirmation in the audio press, to the point where some are treated as facts. The reality is that none of them has in the last fifteen years proved susceptible to objective confirmation. This sad record is perhaps equalled only by students of parapsychology. I hope that the brief statements below are considered fair by their proponents. If not I have no doubt I shall soon hear about it:

"Sinewaves are steady-state signals that represent too easy a test for amplifiers, compared with the complexities of music."
This is presumably meant to imply that sinewaves are in some way particularly easy for an amplifier to deal with, the implication being that anyone using a THD analyser must be hopelessly naive. Since sines and cosines have an unending series of non-zero differentials, "steady" hardly comes into it. I know of no evidence that sinewaves of randomly varying amplitude (for example) would provide a more searching test of amplifier competence.
I believe this outlook is the result of anthropomorphic thinking about amplifiers; treating them as though they think about what they amplify. Twenty sinewaves of different frequencies may be conceptually complex to us, and the output of a symphony orchestra much more so, but to an amplifier both composite signals

resolve to a single instantaneous voltage that must be increased in amplitude and presented at low impedance. The rate of change of this voltage has a maximum set by the frequency response and amplitude capability of the channel and is not generally greater for more complex signals; you do not get hgher slew rate with bigger orchestras. You must remember that an amplifier has no perspective on the signal arriving at its input, but literally takes it as it comes.

"Capacitors affect the signal passing through them in a way invisible to distortion measurements."
Several writers have advocated passing pulse signals through two different sorts of capacitor, and subtracting the result, claiming that the non-zero residue proves that capacitors can introduce audible errors. In fact such tests expose only well-known capacitor shortcomings such as dielectric absorption and series resistance, and perhaps the vulnerability of the dielectric film in electrolytics to reverse-biasing. No-one has yet shown how these imperfections could cause capacitor audibility in properly designed equipment.

"Passing an audio signal through cables, PCB tracks or switch contacts causes a cumulative deterioration. Precious metal contact surfaces reduce but do not eliminate the problem. This too is undetectable by tests for non-linearity."
Concern over cables is widespread, but it can be said with confidence that there is as yet not a shred of evidence to support it. Any piece of wire passes a sinewave with unmeasurable distortion, and so simple notions of inter-crystal rectification or "micro-diodes" can be discounted, quite apart from the fact that such behaviour is absolutely ruled out by established materials science. No plausible means of detecting, let alone measuring, cable degradation has ever been proposed.
The most significant parameter of a loudspeaker cable is probably its lumped inductance. This can cause minor variations in frequency response at the very top of the audio band, given a demanding load impedance. These deviations are unlikely to exceed 0.1 dB for reasonable cable constructions. (eg inductance less than 4 uH) The resistance of a typical cable (perhaps 0.1 Ohm) causes response variations across the band, following the speaker impedance curve, but these are usually even smaller at around 0.05 dB. This is not audible.
Corrosion is often blamed for subtle signal degradation at switch and connector contacts. By far the most common form of contact degradation is the formation of an insulating sulphide layer on silver contacts, derived from hydrogen sulphide air pollution; the problem seems to have become worse in recent years. This typically cuts the signal altogether, except when signal peaks temporarily punch through the sulphide layer. The effect is gross and completely inapplicable to theories of subtle degradation. Gold-plating is the only certain cure. It costs money. A switch with gold-flashed contacts can cost five times as much as the silver version.

"Cables are directional, and pass audio better in one direction than the other."
Audio signals are AC. Cables cannot be directional any more than 2 + 2 can equal 5. Anyone prepared to believe this nonsense won't be capable of designing amplifiers,

so there seems no point in further comment.

"The sound of valves is inherently superior to that of any kind of semiconductor."
The "valve sound" is one phenomenon that may have a real existence; it has been known for a long time that listeners sometimes prefer to have a certain amount of second-harmonic distortion added in, [13] and most valve amplifiers provide just that, due to grave difficulties in providing good linearity with modest feedback factors. While this may well sound nice, hi-fi is supposedly about accuracy, and if the sound is to be thus modified it should be controllable from the front panel by a 'niceness' knob.
The use of valves leads to some intractable problems of linearity, reliability and the need for intimidatingly expensive (and once more, non-linear) iron-cored transformers. The current fashion is for exposed valves, and it is not at all clear to me that a fragile glass bottle, containing a red-hot anode with hundreds of volts DC on it, is wholly satisfactory for domestic safety.
A recent development in Subjectivism is enthusiasm for single-ended directly-heated triodes, usually in extremely expensive monoblock systems. Such an amplifier generates large amounts of second-harmonic distortion, due to the asymmetry of single-ended operation, and requires a very large output transformer as its primary carries the full DC anode current, and core saturation must be avoided. Power outputs are inevitably very limited at 10 Watts or less. In a recent review, the Cary CAD-300SEI triode amplifier yielded 3% THD at 9 Watts, at a cost of $3400 [14]

"Negative feedback is inherently a bad thing; the less it is used, the better the amplifier sounds, without qualification."
Negative feedback is not inherently a bad thing; it is an absolutely indispensable principle of electronic design, and if used properly has the remarkable ability to make just about every parameter better. It is usually global feedback that the critic has in mind. Local negative feedback is grudgingly regarded as acceptable, probably because making a circuit with no feedback of any kind is near-impossible. It is often said that high levels of NFB enforce a low slew-rate. This is quite untrue; and this thorny issue is dealt with in detail in Section 2.5.1. For more on slew-rate see also [15]

"Tone-controls cause an audible deterioration even when set to the flat position."
This is usually blamed on "phase-shift". At the time of writing, tone controls on a preamp badly damage its chances of street (or rather sitting-room) credibility, for no good reason. Tone-controls set to 'flat' cannot possibly contribute any extra phase-shift and must be inaudible. My view is that they are absolutely indispensable for correcting room acoustics, loudspeaker shortcomings, or tonal balance of the source material, and that a lot of people are suffering sub-optimal sound as a result of this fashion. It is now commonplace for audio critics to suggest that frequency-response inadequacies should be corrected by changing loudspeakers. This is an extraordinarily expensive way of avoiding tone-controls.

"The design of the power supply has subtle effects on the sound, quite apart from ordinary dangers like ripple injection."
All good amplifier stages ignore imperfections in their power supplies, op-amps in particular excelling at power-supply rejection-ratio. More nonsense has been written on the subject of subtle PSU failings than on most audio topics; recommendations of hard-wiring the mains or using gold-plated 13A plugs would seem to hold no residual shred of rationality, in view of the usual processes of rectification and regulation that the raw AC undergoes. And where do you stop? At the local sub-station? Should we gold-plate the pylons?

"Monobloc construction (i.e. two separate power amplifier boxes) is always audibly superior, due to the reduction in crosstalk."
There is no need to go to the expense of monobloc power amplifiers in order to keep crosstalk under control, even when making it substantially better than the - 20dB that is actually necessary. The techniques are conventional; the last stereo power amplifier I designed managed an easy - 90dB at 10kHz without anything other than the usual precautions. In this area dedicated followers of fashion pay dearly for the privilege, as the cost of the mechanical parts will be nearly doubled.

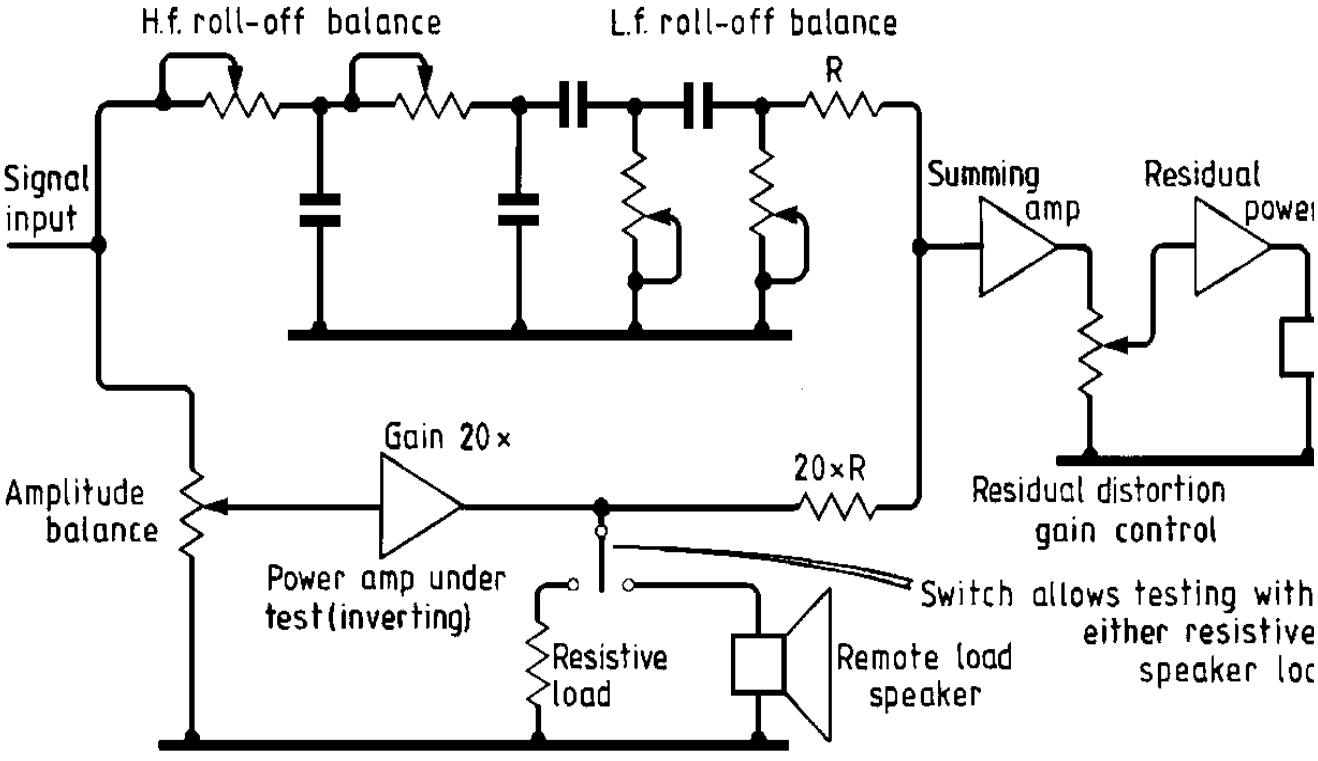
"Microphony is an important factor in the sound of an amplifier, so any attempt at vibration-damping is a good idea."
Microphony is essentially something that happens in sensitive valve preamplifiers. If it happens in solid-state power amplifiers the level is so far below the noise it is effectively non-existent.
Experiments on this sort of thing are rare (if not unheard of) and so I offer the only scrap of evidence I have. Take a microphone preamp operating at a gain of +70 dB, and tap the input capacitors (assumed electrolytic) sharply with a screwdriver; the preamp output will be dull thump, at low level. The physical impact on the electrolytics (the only components that show this effect) is hugely greater than that of any acoustic vibration; and I think the effect in power amps, if any, must be so vanishingly small that it could never be found under the inherent circuit noise.

Let us for a moment assume that some or all of the above hypotheses are true, and explore the implications. The effects are not detectable by conventional measurement, but are assumed to be audible. Firstly, it can presumably be taken as axiomatic that for each audible defect some change occurs in the pattern of pressure fluctuations reaching the ears, and therefore a corresponding modification has occurred to the electrical signal passing through the amplifier. Any other starting point supposes that there is some other route conveying information apart from the electrical signals, and we are faced with magic or forces-unknown-to-Science. Mercifully no commentator has (so far) suggested this. Hence there must be defects in the audio signals, but they are not revealed by the usual test methods. How could this situation exist? There seem two possible explanations for this failure of detection: one is that the standard measurements are relevant, but of insufficient

resolution, and we should be measuring frequency response, etc to thousandths of a dB. There is no evidence whatsoever that such micro-deviations are audible under any circumstances.

An alternative (and more popular) explanation is that standard sinewave THD measurements miss the point by failing to excite subtle distortion mechanisms that are triggered only by music, the spoken word, or whatever. This assumes that these music-only distortions are also left undisturbed by multi-tone intermodulation tests, and even the complex pseudorandom signals used in the Belcher distortion test. [16] The Belcher method effectively tests the audio path at all frequencies at once, and it is hard to conceive of a real defect that could escape it.

The most positive proof that Subjectivism is fallacious is given by subtraction testing. This is the devastatingly simple technique of subtracting before-and-after amplifier signals and demonstrating that nothing audibly detectable remains. It transpires that these alleged music-only mechanisms are not even revealed by music, or indeed anything else, and it is clear that the subtraction test has finally shown as non-existent these elusive degradation mechanisms.



Baxandall cancellation technique. Fig 3.

The subtraction technique was proposed by Baxandall in 1977. [17] The principle is shown in Fig 1.3; careful adjustment of the rolloff-balance network prevents minor bandwidth variations from swamping the true distortion residual. In the intervening

years the Subjectivist camp has made no effective reply.

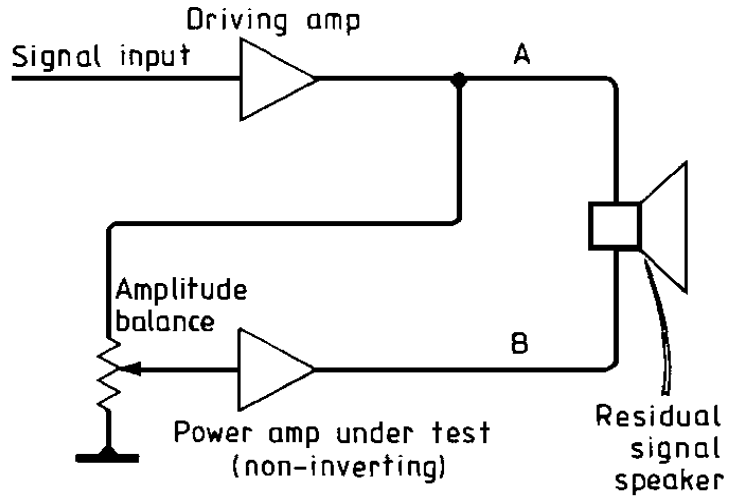


Fig.4. Hafler 'straight-wire' differential test.

A simplified version of the test was introduced by Hafler. [18] This method is less sensitive, but has the advantage that there is less electronics in the signal path for anyone to argue about. See Fig 1.4. A prominent Subjectivist reviewer, on trying this experiment, was reduced to claiming that the passive switchbox used to implement the Hafler test was causing so much sonic degradation that all amplifier performance was swamped. [19] I do not feel that this is a tenable position. So far all experiments such as these have been ignored or brushed aside by the Subjectivist camp; no attempt has been made to answer the extremely serious objections that this demonstration raises.

In the twenty or so years that have elapsed since the emergence of the Subjectivist Tendency, no hitherto unsuspected parameters of audio quality have emerged.

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6: THE LENGTH OF THE AUDIO CHAIN.

An apparently insurmountable objection to the existence of non-measurable amplifier quirks is that recorded sound of almost any pedigree has passed through a complex mixing console at least once; prominent parts like vocals or lead guitar will almost certainly have passed through at least twice, once for recording and once at mix-down. More significantly, it must have passed through the potential quality-bottleneck of an analogue tape machine or more likely the A-D converters of digital equipment. In its long path from here to ear the audio passes through at least a hundred op-amps, dozens of connectors and several hundred metres of ordinary screened cable. If mystical degradations can occur, it defies reason to insist that those introduced by the last 1% of the path are the critical ones.

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7: THE IMPLICATIONS.

This confused state of amplifier criticism has negative consequences. Firstly, if equipment is reviewed with results that appear arbitrary, and which are in particular incapable of replication or confirmation, this can be grossly unfair to

manufacturers who lose out in the lottery. Since subjective assessments cannot be replicated, the commercial success of a given make can depend entirely on the vagaries of fashion. While this is fine in the realm of clothing or soft furnishings, the hi-fi business is still claiming accuracy of reproduction as its raison d'etre, and therefore you would expect the technical element to be dominant.

A second consequence of placing Subjectivism above measurements is that it places designers in a most unenviable position. No degree of ingenuity or attention to technical detail can ensure a good review, and the pressure to adopt fashionable and expensive expedients (such as linear-crystal internal wiring) is great, even if the designer is certain that they have no audible effect for good or evil. Designers are faced with a choice between swallowing the Subjectivist credo whole or keeping very quiet and leaving the talking to the marketing department.

If objective measurements are disregarded, it is inevitable that poor amplifiers will be produced, some so bad that their defects are unquestionably audible. In recent reviews [20] it was easy to find a £795 preamplifier (Counterpoint SA7) that boasted a feeble 12dB disc overload margin, (another preamp costing £2040 struggled up to 15dB (Burmester 838/846) and another, costing £1550 that could only manage a 1kHz distortion performance of 1%; a lack of linearity that would have caused consternation ten years ago (Quicksilver). However, by paying £5700 one could inch this down to 0.3% (Audio Research M100-2 monoblocs). This does not mean it is impossible to buy an 'audiophile'amplifier that measures well; another example would be the preamplifier/power amplifier combination that provides a very respectable disc overload margin of 31 dB and 1 kHz rated-power distortion below 0.003%; the total cost being £725 (Audiolab 8000C/8000P). I believe this to be a representative sample, and we appear to be in the paradoxical situation that the most expensive equipment provides the worst objective performance. Whatever the rights and wrongs of subjective assessment, I think that most people would agree that this is a strange state of affairs. Finally, it is surely a morally ambiguous position to persuade non-technical people that to get a really good sound they have to buy £2000 preamps and so on, when both technical orthodoxy and common sense indicate that this is quite unnecessary.

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8: THE REASONS WHY.

Some tentative conclusions are possible as to why hifi engineering has reached the pass that it has. I believe one basic reason is the difficulty of defining the quality of an audio experience; you can't draw a diagram to communicate what something sounded like. In the same way, acoustical memory is more evanescent than visual memory. It is far easier to visualize what a London bus looks like than to recall the details of a musical performance. Similarly, it is difficult to 'look more closely'; turning up the volume is more like turning up the brightness of a TV picture; once an optimal level is reached, any further increase becomes annoying, then painful.

It has been universally recognised for many years in experimental psychology, particularly in experiments about perception, that people tend to perceive what they

want to perceive. This is often called the 'experimenter expectancy' effect; it is more subtle and insidious than it sounds, and the history of science is littered with the wrecked careers of those who failed to guard against it. Such self-deception has most often occurred in fields like biology, where although the raw data may be numerical, there is no real mathematical theory to check it gainst.
When the only 'results' are vague subjective impressions, the danger is clearly much greater, no matter how absolute the integrity of the experimenter. Thus in psychological work great care is necessary in the use of impartial observers, double-blind techniques, and rigorous statistical tests for significance. The vast majority of Subjectivist writings wholly ignore these precautions, with predictable results. In a few cases properly controlled listening tests been done, and at the time of writing all have resulted in different amplifiers sounding indistinguishable. I believe the conclusion is inescapable that experimenter expectancy has played a dominant role in the growth of Subjectivism.
It is notable that in Subjectivist audio the 'correct' answer is always the more expensive or inconvenient one. Electronics is rarely as simple as that. A major improvement is more likely to be linked with a new circuit topology or new type of semiconductor, than with mindlessly specifying more expensive components of the same type; cars do not go faster with platinum pistons.
It might be difficult to produce a rigorous statistical analysis, but it is my view that the reported subjective quality of a piece of equipment correlates far more with the price than with anything else. There is perhaps here an echo of the Protestant Work Ethic; you must suffer now to enjoy yourself later. Another reason for the relatively effortless rise of subjectivism is the 'me-too' effect; many people are reluctant to admit that they cannot detect acoustic subtleties as nobody wants to be labelled as insensitive, outmoded, or just plain deaf. It is also virtually impossible to absolutely disprove any claims, as the claimant can always retreat a fraction and say that there was something special about the combination of hardware in use during the disputed tests, or complain that the phenomena are too delicate for brutal logic to be used on them. In any case, most competent engineers with a taste for rationality probably have better things to do than dispute every comtroversial report. Under these conditions, vague claims tend, by a kind of intellectual inflation, to gradually become regarded as facts. Manufacturers have some incentive to support the Subjectivist camp as they can claim that only they understand a particular non-measurable effect, but this is no guarantee that the dice may not fall badly in a subjective review.

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9: THE OUTLOOK.

It seems unlikely that subjectivism will disappear for some time, given the momentum that it has gained, the entrenched positions that some people have taken up, and the sadly uncritical way in which people accept an unsupported assertion as the truth simply because it is asserted with frequency and conviction. In an ideal world every such statement would be greeted by loud demands for evidence.

However, the history of the world sometimes leads one to suppose pessimistically that people will believe anything. By analogy, one might suppose that subjectivism would persist for the same reason that parapsychology has; there will always be people who will believe what they want to believe despite the hardest of evidence.

10: SOME TECHNICAL ERRORS.

Misinformation also arises in the purely technical domain; I have also found that some of the most enduring and widely held technical beliefs to be unfounded. For example, if you take a Class-B amplifier and increase its quiescent current so that it runs in Class-A at low levels, ie in Class AB, most people will tell you that the distortion will be reduced as you have moved nearer to the full Class-A condition. This is untrue. A correctly configured amplifier gives more distortion in Class-AB, not less, because of the abrupt gain changes inherent in switching from A to B every cycle. Discoveries like this can only be made because it is now straightforward to make testbed amplifiers with ultra-low distortion- lower than that which used to be thought possible. The reduction of distortion to the inherent level that a circuit configuration is capable of is a fundamental requirement for serious design work in this field; in Class-B at least this gives a defined and repeatable standard of performance that I have named a "Blameless" amplifier, so-called because it avoids error rather than claiming new virtues. It has proved possible to take the standard Class-B power amplifier configuration, and by minor modifications, reduce the distortion to below the noise floor at low frequencies. This represents approximately 0.0005 to 0.0008% THD, depending on the exact design of the circuitry, and the actual distortion can be shown to be substantially below this if spectrum-analysis techniques are used to separate the harmonics from the noise.

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11: ABSOLUTE PHASE.

Concern for absolute phase has for a long time hovered ambiguously between real audio concerns like noise and distortion, and the Subjective realm where solid copper is allegedly audible. Absolute phase means the preservation of signal phase all the way from microphone to loudspeaker, so that a drum impact that sends an initial wave of positive pressure towards the live audience is reproduced as a similar positive pressure wave from the loudspeaker. Since it is known that the neural impulses from the ear retain the periodicity of the waveform at low frequencies, and distinguish between compression and rarefaction, there is a prima facie case for the audibility of absolute phase. It is unclear how this applies to instruments less physical than a kickdrum. For the drum the situation is simple- you kick it, the diaphragm moves outwards and the start of the transient must be a wave of compression in the air. (followed almost at once by a wave of rarefaction) But what about an electric guitar? A similar line of reasoning- plucking the string moves it in a given direction, which gives such-and-such a signal polarity, which leads to whatever movement of the cone in the guitar amp speaker cabinet- breaks down at every point in the chain. There is no way to know how the pickups are wound, and indeed the guitar will almost certainly have a switch for reversing the phase of one

of them. I also suggest that the preservation of absolute phase is not the prime concern of those who design and build guitar amplifiers. The situation is even less clear if more than one instrument is concerned, which is of course almost all the time. It is very difficult to see how two electric guitars played together could have a "correct" phase in which to listen to them. Recent work on the audibility of absolute phase [21], [22] shows it is sometimes detectable. A single tone flipped back and forth in phase, providing it has a spiky asymmetrical waveform and an associated harsh sound, will show a change in perceived timbre and, according to some experimenters, a perceived change in pitch. A monaural presentation has to be used to yield a clear effect. A complex sound, however, such as that produced by a musical ensemble, does not in general show a detectable difference. Proposed standards for the maintenance of absolute phase have just begun to appear, [23] and the implication for amplifier designers is clear; whether absolute phase really matters or not, it is simple to maintain phase in a power amplifier (compare a complex mixing console, where correct phase is vital, and there are hundreds of input and outputs, all of which must be in phase in every possible configuration of every control) and so it should be done. In fact, it probably already has been done, even if the designer hasn't given absolute phase a thought, because almost all amplifiers use series negative feedback, and this must be non-inverting. Care is however required if there are stages such as balanced line input amplifiers before the power amplifier itself.

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