HIFICRITIC ARCHIVE VII

Working in the Front Line

The reviewing experience

Martin Colloms, January, 1991

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A committed audio equipment reviewer operates at the front line of subjective audio judgements. Working on behalf of a readership made up of consumers thirsting for independent, informed opinion and advice, a reviewer is commissioned by the editor of a magazine to produce reports with a technical and subjective content on a wide range of available audio products. These reviews must be both fair and completed at short notice on a relatively small budget.

How is it possible to do this successfully, when a similar task undertaken by an industrial laboratory or test house would take five times as long, cost ten times as much, and deliver a verdict of arguably poorer relevance (footnote 1)

Primary responsibility to the consumer
Any reviewer worth his salt is a crusader working in the best interests of the consumer. In a technical field such as high-quality audio, few consumers are fully qualified to judge absolute performance for themselves; if forced to rely on the advice of retail salespeople, they may not have much confidence in the quality of the advice given.

Working for the audio press, equipment critics are therefore vested with a heavy responsibility: to try to produce fair, consistent, accurate opinions for the guidance of their readers. On the other hand, they also have a duty to be fair to the designers and manufacturers of the audio equipment they write about. Inevitably, some manufacturers object violently when critics fail to agree with their opinions. Others, however, philosophically accept the situation, in the generally positive belief that good equipment will succeed in the end, regardless of occasional reversals, or inaccuracies of individual subjective opinion.

Though we would like to consider that equipment reviewing is a reliable scientific process, and many steps have been taken to make that true, a review remains founded on opinion, of which a large proportion is composed of wholly subjective reactions to sound quality.

The role of laboratory testing
If the reviewer is prepared to spend the money, it is not difficult to set up a sophisticated test laboratory to measure all the standard parameters considered relevant to an audio unit. It is certainly most helpful to have access to detailed lab reports when writing a review. Indeed, such reports are essential if erroneous conclusions are not to be drawn concerning some aspects of sound quality. Some of the commoner pitfalls which can trap the unwary subjective critic include errors

in the RIAA de-emphasis characteristic found in the phono equaliser inputs of preamplifiers and integrated amplifiers. The required equalization is complex, involving three time constants generating nearly 40dB of compensation over the 20Hz-20kHz audio band. I have found mild response turnover and slope errors to be surprisingly common, and these can dominate the reproduced sound. In fact, one of the greatest difficulties concerns the mentally separating underlying quality characteristics from simple first-order errors such as frequency-response aberrations, loudness and channel imbalances.

Subjective effects of first-order errors

Slight errors in channel balance, either in specific frequency ranges or in overall level, can subtly disturb one's opinion of the sharpness of stereo focus. Statistically well-controlled testing has not only confirmed the audibility of absolute phase or signal polarity but also level differences as small as 0.2dB. These differences may range over octave or several-octaves of bandwidth, with an aural sensitivity of a similar magnitude. The subjective responses to variations in amplitude/frequency response are pretty well documented; the careful reviewer bears these constantly in mind. For example, less than 0.5dB, just 5%, of treble lift in the 3-10kHz range can give rise to a mildly increased sense of immediacy, transparency, and liveliness without necessarily being directly obvious as treble lift. A similar degree of loss in the 150Hz-400Hz range can make a vocalist appear lightweight and lacking in power in their fundamental range, conversely lending a crisper quality to the sound. This might be preferred on one recording but disliked on another.

Footnote 1: Originally titled "Subjectivity and Hi-Fi Equipment Reviewing for the Consumer Audio Press," this article, in a somewhat different form, was intended to be presented as a paper at the second "Perception of Reproduced Sound" Conference, scheduled to be held in Denmark in the summer of 1990. Unfortunately, the conference was cancelled due to lack of interest from potential attendees. A collection of the papers presented at the first, 1987, Denmark conference has been published, however, and is available under the title *Perception of Reproduced Sound* from Old Colony Sound Lab, P.O. Box 243, Peterborough, NH 03458, This collection is essential reading for any audiophile interesting in tying the fields of observation and measurement together.—John Atkinson

Errors in frequency response of only marginally greater amplitude may impart subjective alterations in timbre or tonal balance. The sense of "immediacy"—the sensation of proximity to the performers—may also be affected. Perspective—the feeling of front-to-back distance in the soundstage—is a related parameter. Other effects include the feeling of transparency in the reproduced sound. Loudspeaker designers become keenly aware of these subjective effects, which may be deliberately designed- in and otherwise hidden within the normal tolerances of the amplitude/frequency responses of a nominally well-designed loudspeaker system.

Unscrupulous speaker designers have frequently exploited such subtle changes in energy balance to result in a design with a particular accented subjective parameter. Such designs may well be commercially successful for a while; ultimately, however, a consensus develops among listeners indicating that a particular design favours one class of music or type of recording over another, and the trick is exposed, if still not fully understood.

Loudspeaker reviewing problems
If hi-fi reviewing is considered in general to be a hazardous undertaking, the speciality of loudspeaker assessment must rate as a veritable minefield. There is so much potential here for inconsistency of opinion that test results need to be most carefully balanced before appearing in print.

Factors to take into account include:

1) the listening-room environment and its relationship to the specific design of speaker;
2) the mounting and placement of the speaker
3) matching to the associated audio chain, including the amplifier load drive and the maximum available headroom.
4) the good taste and judgment of the critic or critics , which will remain a dominant factor.

Without going into great detail on the subject of loudspeaker assessment, it is worth noting that a considerable quantity of interesting and revealing laboratory data can be amassed for a particular model. These measurements may indicate that a given design could not possibly be a poor performer, yet conversely, no amount of good measurement results can guarantee that a loudspeaker is substantially good and will therefore be the beneficiary of great reviews and generate successful sales in a competitive market. The history of high fidelity is littered with superbly engineered loudspeakers which have measured well but never made it in the real world. How does the subjective reviewer explain to a designer that his brainchild does not sound involving or interesting when he only believes in graphs and meter readings?

For equipment as a whole, good lab technique is a vital part of reviewing and acts as an error trap, identifying common design weaknesses and faults, and the effects of manufacturing tolerances. There is always the temptation, for the reviewer to use the lab results as a foundation on which to base his or her arguments. Subjectivity again holds sway, both in the gathering and in the interpretation of such measurements. If the product is judged to sound weak, measured weaknesses may be brought into undue focus. Conversely, if the unit is favoured, the reviewer must then guard against the human tendency to ignore or gloss over measured imperfections in a bout of enthusiasm.

Subjective opinion & sound quality
The assessment of sound quality is the foundation of a good review; without it, the review is almost worthless. Yet how can sound quality, in its broadest sense, be accurately assessed without recourse to the time and expense of fully validated statistical testing? Many scientists and members of the audio establishment would prefer not to hear the answer: The ability to assess sound quality is not a gift, nor is it a feature of a hyperactive imagination; it is simply a learned skill. Like any skill, it is acquired by example, by relevant education, and by practice. A basic understanding of music is helpful, not least because much of the subjective characterization is necessarily based on musical terminology and critique. Regular experience of live music-making is exceedingly valuable in order to refresh one's aural memory for natural sound. The latter must form the

true foundation of all subjective assessment.

Subjective assessment should be a disciplined process, but should not be so rigorous as to exert undue stress on the assessor. It is a well-observed fact that a person's sensitivity to subtle but worthwhile sound-quality differences reduces to near-invisibility under stressful and trying test conditions.

For example, it is well known to most critics that if you arrive at a situation where differences appear to be small, the harder you try to hear them, then the more impossible the task becomes. On such occasions, a scheduled rest, a change of program, and a conscious effort to relax and distance one's immediate concentration on the matter at hand, generally lead to a recovery in acuity. Paradoxically, the less the critic personally cares about the outcome of a test, the more aware he or she is of the subjective quality differences concerned.

Greatest awareness of the long-term quality of an item is generally obtained by the single presentation method, while maintaining critical control of absolute level and channel balance, combined with an awareness of any relevant response errors. Initially, single presentation techniques were confined to loudspeakers; later they have been extended to cover RIAA preamplifiers, pickup cartridges, tuners, power amplifiers, and then preamp line stages and CD players. Finally, the technique has been applied to the reviewing of audio cables and problematic passive components such as resistors, inductors, capacitors, and even printed circuit boards (pcbs) and pcb tracks.

A whole multitude of subjective differences have since been identified which consistently relate to observed engineering differences. At present, however, established measurements have great difficulty in elucidating these differences; as a consequence, most academics tend to regard their discovery as irrelevant. Such sceptics would certainly not like to hear that a number of audio critics can reliably identify the sound of specific kinds of metallic conductor used in audio cables.

If it is accepted that such effects exist, it is our duty as engineers and scientists to understand and control them to our advantage.

The High End

If any sense is to be made of it, then true high-quality audio, the "High End," must be set apart from the audio business as a whole. The quality audio business is a relatively small, specialist industry composed mainly of companies run by enthusiasts, who in the main believe in what they're doing, namely the advancement of the fidelity of reproduced sound. Nevertheless this industry is founded on a solid scientific base, melding mechanics, acoustics, and electronics to advance the listening experience. Its top designers have learned to mistrust a significant proportion of conventional scientific wisdom, having found that it did not adequately describe or control the observed subjective aspects of equipment design and performance.

This is also true for professional equipment reviewers. Using natural sound as the ultimate arbiter, they have been increasingly driven to use a greater proportion of subjective assessment to successfully differentiate between the products under review.

From a greater audio perspective, an outsider could legitimately ask ‘what is the point of pursuing such small audio differences in sound quality when audio reproduction as a whole is more or less perfect?' There are also those who say that the available engineering results prove that reproduced sound is about as good as it needs to be, given our limited ability to control the acoustics of the listening room. Conversely, others who are very familiar with the sound of live music, judge reproduced audio to be a travesty of the truth, and refuse to take it seriously.

Both sides of this debate are often outraged by the large sums of money asked and paid for high-quality audio equipment; they appear to take comfort from the belief that the industry is engaged in some sort of elaborate deception, hoodwinking the unsuspecting public. Nevertheless, the subjective properties of high-quality audio equipment are real, and are both readily perceived and valued by enthusiasts who want to spend their cash as wisely as any other careful consumer. It is not the function of academics to tell someone what he or she should or should not want.

Subjective testing in other fields

A classic example of subjectivity in action is the assessment of wine. Those practiced in the technique can perform seeming miracles of discrimination, analysis, and even specific identification, both of a wine's origin and year. Such abilities, hardly a matter of public dispute, form the basis of quality control and assessment for a vast industry, where the final price relates very little to the chemical composition of the end product. The price asked for a bottle of wine depends on how you and others value the pleasurable subjective response that is derived from its consumption. The subjective analysis of the quality and worth of wine is a learned skill from which we all can benefit. There are, of course, many who care little for the difference between an ordinary and a great vintage, but craftsmen do not work their skills for undiscerning customers.

There is a distinct parallel between this and the purchase of a good-sounding power amplifier. Here the designer's skill has ideally resulted in an exceptionally accurate sound, an achievement which parallels that of a vineyard manager who nurtures a superb growth. Such creations must be worth more than run-of-the-mill products.

Subjectivity overrules engineering in many other fields; for example, in the manufacture of musical instruments, or the technique of a good chef. A concert-goer familiar with good music-making is immediately aware whether an orchestra is playing well, and if the conductor has a good relationship with the band. Interestingly, one of the subjective effects of poor quality audio equipment is to give the strange impression that the orchestra is not playing well. This aspect cannot be associated with any single specific measurement at present.

Subjectivity in audio reproduction does not always have to be reduced to the lowest common denominator and be forced to endure the insensitive scientific methods of double-blind trials to prove its validity.

How to get an academic paper published

A paper presented to an academic body or published in a learned journal is subject to referees, supervised by an experienced periodicals editor, and may likely be supported by colleagues or refereed by senior members of the community, before seeing the light of day. Such procedures are intended to filter out lower grade material and ensure that the paper is worthy of publication in the respective journal. By contrast, many submissions to the consumer press are of dubious worth, and sometimes their claims horrify the scientific community, which prides itself on intensive research based on tried and tested methods.

Many of the advances made by the industrial world rely on such established practice and, above all, the correct mental attitude. Young scientists are trained—I would hesitate to say brainwashed—to comply with the status quo. They are instructed to follow the established advice and direction of their mentors. However, academic structures are generally conservative, opposed to change, and poorly receptive of new and radical ideas.

Such attitudes tend to suppress freedom of thought and innovation. Furthermore, science is littered with discoveries which were largely accidental; had they been ignored simply because they did not conform to the status quo, the loss to mankind would have been incalculable.

Examples include the chance arrival of the airborne penicillium mould in a particular scientist's laboratory, while centuries earlier, Kepler had been attempting to solve the problem of planetary motion within the conventional paradigm. Ptolemaic and Copernican laws only allowed for purely circular orbits. Kepler's discovery that the orbits must be elliptical was something he could not wholeheartedly believe in, and he referred to it as merely a computational device, yet this discovery led to a wholly new framework of physics later developed by Galileo and by Newton.

"The active researcher must see beyond the imprisonment of the prevailing paradigm, and if so led by observation, he must be allowed to go beyond the boundaries of what is considered true or plausible."

"Science can benefit from a hint given by Nature only if there are open-minded scientists who grasp the significance of a hint."

"Serendipity supplies science with its blind edge...allowing scientists...to transcend established frameworks of knowledge, established world pictures." (footnote 2)

This applies most strongly to the assessment and analysis of reproduced sound quality, where variables exist for which there is no good engineering framework.

Do CD players sound the same?

We will assume, for the purposes of argument, that all CD players under this consideration have correctly operating error protection, an excellently flat frequency response, near-perfect channel balance and separation, and, by present standards, negligible non-linearity or related distortions. Let us also assume that all have low output impedance and a nominal output of 2V RMS for 0dB, full modulation.

Conventional wisdom tells us that these are essentially perfect sound sources; remember the original CD slogan, "Perfect Sound Forever." Yet my experience of a very large sample of 300 models, with approximately 30% of repeat auditions, has been that CD players do *not* sound the same. Very little correlation can be shown between sound quality and exaggerated technology claims or lab measurements, even when the latter are of extraordinary sensitivity. For example, transfer linearity is routinely measured better than 115dB for dynamic range, with frequency response and balance held to ±0.01dB tolerances, and distortion to a threshold 120dB below peak level.

However, great correlation is shown between the generic types of player, both in terms of absolute merit and detailed subjective characterization. It is accepted that there exists a genuine scale of absolute reproduced sound quality for audio equipment, which generally improves in proportion to the cost. In the case of CD players, a similar relationship for sound quality is also apparent.

Having begun a scale of subjective merit for loudspeakers using scores from 0-10, representing no merit at one end of the scale to the best possible at the other, I transferred this method of ranking to amplifiers. Some years and some 150 amplifiers and preamplifiers later, a problem developed. Equipment was improving, something regularly verified by returning to long-term references. The best-sounding models were now being marked in a more logarithmic fashion, bunched in the range between 9 and 10 on the scale. This could not continue indefinitely, and I decided to make the scale open-ended—to reassess the top performers, and to give them corrected scores that bore an observed proportional relationship to the earlier references.

Over the years, assessments have seen the current "state of the art" score move from the original "10" to "13," then to "18," and in 1990, to "24." The percentage ratings I gave in published reviews were based on the state-of-the-art value in force at that time. A component currently earning a merit grade of 12 when auditioned, a budget design for example, therefore got a worthy 50% overall rating in print.

When assessing CD players a mental attitude can be adopted which helps free the listeners from concerns about the medium and its initially fascinating technology. Since the music emanates from a constant source—the optical disc recording—and since it emerges at line level, fully equalized, it has proved to be quite convenient to conceptually consider a player as just another line stage in a quality preamplifier. A similar merit-assessment procedure and similar criteria are therefore used for CD players. Some 300 players later, this premise is still valid, and CD-player sound characteristics are closely allied to fundamental differences noted with various qualities and types of electronics used in audio amplifiers.

The very first CD players scored in the ‘6-7 out of 10’ range; they were clearly inferior not only to the best contemporary electronics but also to the better analog, LP turntables. This came as a huge disappointment to many enthusiasts, including myself, who expected great things from the CD medium, and who hoped that the merits of the technology were cut and dried. Though the early players were at first impressive sonically and most cleverly automated, the pleasure gained from the silent surfaces and slick facilities gave way to subjective boredom and, ultimately, to significant listening fatigue. The syndrome I noticed with early CD replay is a common one among hi-fi fans. This is where the protagonist plays many excerpts from demonstration tracks, but never settles down to enjoy a complete performance.

Footnote 2: Kantorovitch & Ne'emen, *Studies in the history of Philosophy of Science*, Vol.20 (Tel Aviv).

It took a full three years of commercial development before CD sound broke through the score "10" level, which in 1990 actually represented the average for the whole industry. Players scoring 5 on the then current 24-maximum scale are usually found in cheap music centres, while a player that won respect in the more critical areas of the industry scored 14 or more. Genuine audiophile players were rare and scored above 16, generally costing in excess of $1000. Later high-end players and processors using both one-bit Delta-Sigma BitStream and multi-bit DAC technology have shown that a score of 24 is attainable; no doubt this reference level will be bettered in the future by further design refinements.

Those who do not care, either consider such differences inaudible, or deliberately deem them irrelevant or inconsequential. However, these differences are crucial factors in determining equipment purchase for those who do care and do listen.

Comparisons may be drawn between some of these subjective differences and those found in the more familiar area of loudspeakers. For example, the treble reproduction of a good pure ribbon or electrostatic drive-unit can reach a high standard of naturalness and purity. The contrast with a budget dome or paper-cone tweeter is an obvious one, the latter often characterized by grainy, sibilant, and fizzy effects combined with a masking of fine detail and harmonic subtlety. Moreover, these differences would seem to be confirmed by delayed resonance and frequency response measurements.

When a CD player is evaluated with a ribbon or equivalent high-quality transducer in the chain, treble differences may be observed which resemble those that would result from substituting an inferior tweeter for the loudspeaker. Yet in the CD case, there is no obvious measured parameter that correlates with this aspect of performance.

Moving down in frequency, varying the total "Q" factor of a loudspeaker system's alignment at low frequencies leads to measured changes in bass response that relate quite well to the subjectively observed differences. A similar subjective variability in bass quality, akin to Q variations in a loudspeaker system, can be heard between CD players of identically and perfectly flat frequency response, generally extended (-3dB) to below 3Hz, for which there is no good explanation.

Well-behaved loudspeakers of low stored energy characteristic, and uniform axial and off-axis frequency responses, tend to sound quite good. They can also present good stereo images, developed with a pleasing impression of image depth where the recorded material so allows. We also know that a more resonant type of speaker tends to mask low-level detail, ambience clues, and the like, and may produce "ping-pong" stereo with little depth or ambience. Strangely, a comparable effect may be heard with CD players; some give a rather flat, sterile image while others deliver rewarding levels of depth and clearly reproduced ambience, corresponding well to the original recorded acoustic.

Again, no existing measurement can pinpoint such observed variations.

A further aspect concerns timbre, or tonal balance. Anyone who has recently heard natural orchestral string sound will testify that most reproduced string tone is actually a travesty, even when reproduced with high-quality equipment. All the processes involved in recording and reproducing seem to impart a cumulative hardening, an embrittlement and congestion to orchestral strings (see Sidebar). CD players are no exception, and significant differences can be observed between them. As with the other subjective parameters discussed, this variation is not amenable to laboratory analysis. Weighing these timbral differences in the context of the sound from a loudspeaker, one might suspect significant, subjectively equivalent variations of as much as 1.5dB magnitude in the lower presence-range octave; *e.g.*, from 1kHz to 2kHz.

Now for still more contention.

The sound quality of passive electronic components: capacitors, resistors, inductors, cables

Surprisingly small differences in subjective sound quality can be reliably identified. For example, listening tests have revealed audible differences between groups of metal-film and other types of resistor used in audio equipment (footnote 3). In these tests, the listeners had no interest or foreknowledge of the resistor types, and would not have known how to identify them even had they felt like trying. These results have been given strong practical confirmation in real amplifier designs.

Similar subjective tests involving capacitors (footnote 4) have resulted in a number of improved-sounding components which are employed in loudspeakers and amplifiers. In one double-blind listening sequence, a group of electrolytic power-supply capacitors was assessed for their contribution to the sound of a complete high-grade stereo amplifier. All of the capacitors tested were used well within their ratings. However by design, their internal design, foils, and electrolyte chemistry were different. The capacitors were properly ‘formed’ for the test, then uniformly disguised, and soldered directly into the power amplifier circuit by an independent operator located remotely from the listeners. There were no other variables in the experiment. The listeners were asked both to assign merit scores to each presentation and describe the sound quality.

The results showed good consistency for the limited number of repeats employed; the engineers involved were astonished to find that the capacitor differences were highly significant, in fact determining between 20% and 30% of the overall performance of the amplifier. Each type showed complex differences in virtually all of the normal subjective audio characterizations, including bass damping, stereo focus and depth, timbre and treble distortion, and/or treble brightness. No lab measurable differences were observed for the complete amplifier using any of these capacitors.

Footnote 3: Martin Colloms, "Pièce de Résistance," *HFN/RR*, June 1987. See also Hephaistos, "Enquête sur des résistances au-dessus de tout soupçon" (An investigation into resistors above all suspicion), *L'Audiophile*, Paris.

Footnote 4: Martin Colloms, "A Capacity to Change," *HFN/RR*, October & December 1985.

Another revealing example is the effect of printed circuit boards on amplifier sound quality. In one example, an amplifier was prototyped in hardwired form using phenolic paper pin board, with a physical layout and connection wiring precisely conforming to a correctly designed printed circuit board. Thoroughly measured and auditioned, it gave an excellent performance. Second prototypes were then built using pre-production pcbs. By exhaustive measurement, the two were judged to be almost identical in the lab, yet the sound quality of the second version was significantly poorer.

After some investigation, the pcb substrate was suspected; several complete prototypes were therefore made with different board dielectrics; *eg*, bonded paper and glass epoxy. Different foil thicknesses and copper purities were also tried. All measured well, yet all showed further sound-quality differences, the work leading to identification of a satisfactory compromise.

Conventional electronic wisdom indicates that while pcb quality may be relevant above 50MHz, it is of no importance to audio amplification working at less than a hundredth of that frequency. While this may be true for non critical applications, where sound quality matters and where sensitive critical auditioning is involved, not even the printed circuit can be left to chance.

When a single high-quality plastic film capacitor can be audibly identified under double-blind conditions, perhaps it is not so surprising that the much poorer dielectric of a pcb has an audible effect on a high-quality amplifier.

Still less welcome to the engineering establishment is the discovery that audio cables vary in their subjective accuracy; if rather less than most amplifiers, but nevertheless in ways which can be described and ranked on merit.

With the finest of today's systems the best cable is fortunately close to invisibility in audio terms—the ideal condition. The results from cable reviewing suggest that the use of poor or inappropriate cabling leads to an overall loss of up to 30% in subjective performance in a state-of-the-art system.

The significance of cable quality is understandably proportional to the quality of the reproducing system, and becomes irrelevant in the context of rack systems and similar fundamentally compromised systems. The primary requirement for assessing small sound-quality differences is that the reproducing system used must be of the highest available quality, chosen by a combination of trial, experience, and informed opinion. It must then be optimally set up and installed in a room possessing favourable acoustics, and fed neutral, high-quality program. Put bluntly, there is no point in attempting to quantify the perceived depth in a stereo image illusion if the system is incapable of reproducing it, or if the source material lacks the necessary recorded information.

A wine taster cannot perform when using dirty or contaminated glasses; likewise, an art critic cannot make reliable judgments when wearing shades.

Detailed comparative tests made on audio cables have brought to light a diversity of previously unsuspected and therefore neglected factors which have subjective consequences:

• Dielectric: A good correlation has been observed between dielectric loss and sound quality. A vacuum insulator shows the lowest loss, followed by air, and then by a range of dielectric materials commonly used for cables of all classes. The subjective ranking correlates with their dielectric properties. Thus, foamed or predominantly air-spaced types with PTFE, polypropylene, and polyethylene dielectrics score highly, while higher-loss materials such as PVC are distinctly inferior, even to the point of generating identifiable colorations and changes in timbre.

Associated with the subjective performance of the cable dielectric is the insulating thickness, this often related to the manufacturer's voltage rating. Better sound often follows higher ratings. Solid dielectrics are common and include those plastics mentioned above, as well as higher-molecular-weight polymers, ceramic powder, silicone rubber, and resin-impregnated glass fibre. Natural thread such as cotton or silk has been tried, plus various grades of carbon-based rubber. Every dielectric can be shown to have its own distinctive sound, even when used in a line-level interconnect application of just 1m in length.

• Metallurgy: Many establishment audio engineers consider that Ohm's Law is wholly sufficient to describe current flow in a wire, and that all metallic conductors must sound the same owing to the fundamental property of free electron mobility in this class of material. However, there is now strong evidence to indicate that the choice of element or alloy for a conductor, its metallurgical history, and its absolute purity all affect the sound quality. This finding, unwelcome for those working in this field, cannot be ignored. It seems a cruel twist of fate that of the many conducting materials tried, high-purity silver sounds the most accurate, as it costs approximately 100 times as much as the substantially effective and most widely used material available namely copper.

Some physicists approached on this subject have invoked quantum theory to analyze the behaviour of metallic conductors in varying states of practical purity, particularly with respect to the boundaries between metallic crystals.

• Geometry: The physical design of a cable is another variable which affects sound quality. There is a strong association between a balanced symmetrical twisted pair or twisted quad construction and a sound quality that is judged to be superior to a coaxial construction. The form of the conductor also matters—whether it is solid-core or stranded. Generally, the single strand is preferable unless the wire is of unusually high purity, and the strands are bound in intimate electrical contact.

Cable assessment

For cable assessment, the reference should be taken to be an *absence* of cable in that particular link, achieved by positioning the program source very close to the next unit and joining them by pure silver wire links barely 20mm long. The cables under test are substituted for this near-perfect link and their negative sound-quality characteristics assessed. In a recent test (footnote 5), 50 interconnect cables were successfully analyzed subjectively by using the single presentation method. Occasional return to the reference helped refresh the memory, while repeats constituted 25% of all the tests and gave reasonable confidence in the reliability of the judgments.

Conclusions

This article has barely touched on the wide scope of the judgment of sound quality of audio components for review. While it is readily acknowledged that the bulk of the listening tests mentioned are not based on established "scientific" procedure, control methods have been used as far as is possible, However, if "scientific" methodologies had been adopted, many of these results would not have been observed—not, as the cynics would have you believe, because the differences do not exist, but because rigorous subjective testing requires an inordinate time scale, often imposing sufficient stress to desensitize the subjects.

In one well-researched case, however, a pair of good-performing, extensively measured amplifiers was found to be easy to differentiate by ear under normal review conditions, one being clearly more accurate than the other (footnote 6). A single presentation test was subsequently devised for a meeting of the London AES, where a large number of listeners (90 or so) participated in a controlled listening experiment to see a) whether two amplifiers could be differentiated, and b) whether one was preferred to the other. The judgment method required that the audience score each presentation as a new trial, this constituting the database. On first publication of the results (footnote 7), some colleagues helpfully pointed out certain analytical weaknesses (footnote 8).

Sufficiently good data were obtained, however, for a statistician to confirm the validity of the test and find that while the aural sensitivity of the unscreened AES members under the difficult conditions of a public meeting was not very good, they nonetheless were able to collectively discriminate, and moreover did prefer one amplifier to the other. This agreed with the original review findings. The test was exhaustively researched with regard to load matching, absolute level, and the like. CD was the program source, and no switch box was involved.

Good hi-fi reviewing has moved beyond the basic framework of a comprehensive lab test and engineering analysis, coupled with rote descriptions of finish, facilities, and ergonomics and followed by a cursory listening check to make sure all is in order. Extensive listening work using consistent and methodical techniques, especially numerical scoring, has shown that many engineering factors are responsible for audible changes in reproduced sound quality, not least in absolute merit. At present the electronic and acoustic establishment dismisses many of these issues.

Subjective assessment is a learned skill, one which is greatly helped by a familiarity with and an understanding of music. Frequent acquaintance with live, natural sound is also vital. Such a skill may be used routinely to judge fidelity, without persistent demands to prove the results statistically.

The best high-fidelity products can be seen to be the result of an alliance between good engineering science and the art of high-quality music reproduction. The leading audio designers make no secret of the absolute necessity for them to practice or purchase the skill necessary to judge the sound quality of their creations at every stage, from conception to production.

Fundamental research is necessary to track down and quantify the many causes of sound-quality variations now familiar to discerning reviewers.

Footnote 5: Martin Colloms "Fifty Cables," *HFN/RR*, July 1990. See also Martin Colloms "Cable Talk," *HFN/RR*, June 1987, and "Cable Considerations," *HFN/RR*, December 1985.

Footnote 6: Martin Colloms, "Pot Pourri," *HFN/RR*, January 1985.

Footnote 7: Martin Colloms and Rosamund Weatherall, "Amplifiers Do Sound Different," *HFN/RR*, May 1986; also see Martin Colloms's and M.E. Le Voi's further analysis of the London AES amplifier test results, "Views" (Letters to the Editor), August 1986.

Footnote 8: Notably Stanley Lipshitz in a private communication.

Sidebar: Massed violins & digital sound
Why should the sound of massed violins should be so susceptible to processing damage? Given that all links in the chain are non-linear to some degree, either in terms of transfer function or in terms of delayed energy storage, the potential for audible damage to a given musical signal is proportional to its complexity. The intermodulation products for just a few tones look horrifying on a spectrum analyzer display. Imagine a musician sounding two notes on his violin: high-order harmonics are predominant, with perhaps 15 significant components. Then add the full orchestral complement of up to 20 players. Each will have a fractionally different tuning; in any case, their sounds are subject to differential delays en route to the microphone. Add in the contribution of floor reflection, a further delay. Add in the cumulative sound in the reverberant field.

The resulting massed string sound might well possess in excess of a thousand significant, recordable harmonic constituents. The build-up of multiple cross and intermodulation energy of an enharmonic nature is clear enough, and may well explain the very evident distortion heard on reproduced strings in the audible range. It is highly significant that the direct feed from a recording microphone to a good pair of monitor amplifiers and speakers shows very much less of this familiar audio distortion.--**Martin Colloms**