Proofs of an Absolute Polarity

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PROOFS OF AN ABSOLUTE POLARITY

"Absolute polarity is an interesting phenomenon [wherein] those who don't hear the effect mostly doubt the opinion of those who do." [John Roberts, AES]

A newly-devised test (herein called "triple-blind") once-and-for-all assesses polarity audibility variously among audio engineers, hobbyists and musicians. Results decisively affirm the sensation; many trial subjects moreover testify that Absolute Polarity's palpable reality constitutes an essential addition to the audio engineering armament.

0. INTRODUCTION

What is Polarity?

Phase, a term that describes non-synchronous aspects of electrical signals, and **polarity** are not interchangeable although often confused. Phase is relative and may assume any value over the entire frequency spectrum; polarity has no magnitude, is either positive or negative. Phase may vary with time, but polarity remains timeless. The two terms cross paths in the unfortunate, ambiguous phrase "out of phase."

Polarity pertains two ways to any alternating electrical signal. While both DC and AC have "hot" and "cold" designations, another polarity exists in the AC longitudinal direction, described by "compression" and "rarefaction." Musical instruments produce waveforms of enormous complexity and asymmetry. However, the leading wavefront -- the initial stroke -- defines an audible characteristic beyond phase (the time-variant overtone structure or "timbre"); this stroke is acoustic polarity.

What is Absolute Polarity?

The term Absolute Polarity uniquely describes the correct arrival to the ear of acoustic wavefronts from transducers, with respect to actual musical instruments. Electronics often reverse positive and negative, inverting compression to rarefaction and *vice versa*. The human ear distinguishes the two modes and hears music differently when presented with the wrong one -- again *with respect to actual musical instruments*. Hence the standard referred to as "Absolute" is actual music, no mere definition on paper.

Moreover, Absolute Polarity is a "monaural phase effect" (MPE) unrelated to "stereo" or "soundstage," and as such was discovered by Rosenblith and Rosenzweig [1952] at Harvard. Employing clicks in headphones, they found that compressions were audibly different from rarefactions. Confirmation came later from Jeffress and Craig [1962], who named the effect after its nominal founder, Charles E. Wood. Still an experimental MPE, the advent of stereo was far distant, at least from psychoacoustics, before it occurred to anyone that musical instruments produce complex click-like wavefronts too, and electronic reversals here

might be detected equally well. That singular aural phenomenon defines Absolute Polarity: the concept that polarity inversion can be heard, requiring that reproduced sound maintain the same wavefront approach as real instruments.[1]

1. AUDIBILITY OF POLARITY

No consensus exists in the engineering community on how to regard Absolute Polarity. Divergent views cut across every boundary in audio and acoustics. Although one study demonstrated audibility in double-blind tests to the 99% confidence level, many who cannot hear it themselves firmly demur, without pointing out specific flaws in the tests. The present study hopes to improve upon previous efforts by elevating procedures to a higher level of credibility. But let it be said here at the outset, the author advocates Absolute Polarity and can reliably identify it, yet would never attempt to adjust results on any test.

The extensive printed testimony to Absolute Polarity might be summoned at this point, but shall be deferred for now to discuss rather what one hears. Incorrect Polarity has been called the "muffling distortion"; it blunts the attack, pulls the punch, softens music to a dull roar. Correct Polarity charms the listener with:

- heightened articulation, especially in the bass
- uncompressed transient response (*e.g.* crispness on percussion)
- enhanced timbral beauty and bloom
- increased palpability in throat, chest and gut
- improved speech intelligibility

All for what amounts to a simple switch of wires. It seems too good to be true: Who can believe, better sound for free? Yet readers may affirm for themselves the veracity of polarity by experimenting with their own resident band of musicians. Comparison to various "stereo systems" and recordings will yield an ineluctable result: the band always sounds right but

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[1]The unusual notion of MPEs was reaffirmed in *Journal of the Audio Engineering Society* ("Subjective Measurements of Loudspeaker Sound Quality and Listener Performance," January/February 1985), where Floyd E. Toole reported that listeners are more critically sensitive to monophonic tests: "The results from interleaved mono and stereo listening tests indicated that...in stereo listeners tended to be less offended by problems that elicited strong criticism in mono tests."

sometimes the hi-fi sounds very wrong, very muffled. The correction procedure is like learning a musical instrument, although the process may be fraught with error, as explained below. Suffice to say, whoever teaches himself to hear polarity, knows it forever.

2. PROBLEMS OBSCURING PERCEPTION

One might well ask, if Absolute Polarity is so essential, why has it not been universally embraced? Indeed, dozens of writers have attested to its importance, as revealed shortly in Section 3. *JAES* has mentioned Absolute Polarity no fewer than five times (always favorably), the popular audio press has broached it (usually unfavorably) and "the high-end" irregularly covers it. If true, here is a marvel of science confirmed by numerous listeners -- yet despised and rejected in many circles. No wonder the average consumer feels confused.

All can be forgiven, however, because several factors obscure the perception of Absolute Polarity.

(1) *Difficult to Demonstrate.* The author once assembled an audio system where, luckily, polarity was obvious. Gradually he discovered why so many others had missed it: most loudspeakers are phase-incoherent. Minimum phase distortion has never been in vogue, so many systems incorporate hundreds *or thousands* of degrees of phase error.[2] Our oft-declared inability to hear phase has resulted in loudspeakers where even a complete 180^{o} phase reversal cannot be detected. Yet, over a simple transducer with gentle crossovers and no **inversion catastrophe**, Absolute Polarity is apparent to nearly everyone.

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[2]The sources were isolated over ten years ago by R.A. Greiner and Mark Allie ["Manipulating the Response of Multiway Loudspeaker Crossovers," AES Preprint 1761 (E-2)]: "It is clear that only the single pole response is perfect and that even that can be spoiled by inverting the polarity of one of the drivers. The transient responses of the second and third order filters are not very nice looking, but certainly, the summed outputs are better than those with inverted polarity...While inverting the polarity may not change or may 'improve' the amplitude response of some filters, the transient response is drastically affected for the worse...The transient responses have been investigated...and show the 'inversion catastrophe' typical of all crossover schemes that utilize negative or alternately inverted polarity to the drivers. Such negative or inverted connections should be avoided in our opinion...[They are] fundamentally flawed."

(2) *Some Confusion*. Recorded polarity comes two ways, but only one is correct for a given system. Much confusion results from freely mixing them. Daily exposed to mixed and incoherent signals, even otherwise careful listeners become accustomed to ignoring polarity.

(3) *No Meter Indicator*. Some meters *do* indicate, however, as revealed in Reference 1988 (May), but these are obscure, although one such has been effectively in service since 1955.

(4) *No Regular Variable Changed*. The usual specifications sought by (and supplied to) consumers remain unchanged by polarity: Gain, Frequency Response, Harmonic and Intermodulation Distortion, Signal-to-Noise Ratio, *etc*. Nor are speaker positions or room acoustics affected.

(5) *Switches Ineffectual*. Front panel switches for Absolute Polarity appear increasingly on electronic gear, especially CD players. Why these sometimes hardly work remains a mystery, although they do lead many to doubt Absolute Polarity. A simple switch of wires works much better.

(6) *Incoherent Recordings*. Polarity (an MPE) may be heard best over a single channel recorded with one microphone. Multi-microphones and multi-channels only complicate the situation. Fine stereo recordings do exist where polarity is perfectly obvious -- although a close-miked soloist may be reversed from the orchestra. The more recent sort of recording, to which almost the entire industry has succumbed, involves not only multiple microphones and channels, but imposition of "studio toys" in the "post-production mix." Insofar as their polarities are random and engineers remain incognizant, recordings ever more fail to reveal Absolute Polarity.

(7) *Lack of Standards*. Only Stodolsky [Sept 1970] has attempted to effect overall standards, although desultory moves have been made elsewhere. One serious recent effort concerns an AES "Recommended Practice for...XLR-Type Polarity and Gender." The draft proposal envisions "to provide a common scheme...to avoid the inversion of absolute polarity among the items in a single chain." Unfortunately the scheme falls short of the mark; Absolute Polarity refers specifically to acoustic wavefronts as they reach listeners' ears, a destination unaddressed by the draft. What this standard *might* do is remove another barrier to

comprehension, because XLR pin polarity was once found to be split 50/50 [1984 (April II)].

(8) *Shortage of Literature*. No audio periodical regularly addresses acoustic polarity, nor does any reference book discuss it, certainly not in English. For example, John Borwick's estimable *Loudspeaker and Headphone Handbook* carries no indexed entry, nor does Tremaine's *Audio Cyclopedia*, nor Laura Dearborn's "high-end"-oriented *Good Sound*. (Dearborn now edits *The Absolute Sound*, whose publisher, ironically, declines to acknowledge Absolute Polarity.) Even Floyd E. Toole's otherwise comprehensive work as conveyed in *JAES* contains no specific awareness here; his list of twenty-three "nuisance variables" that cause "fluctuation in opinion" omits Absolute Polarity. Nor does this vital factor appear in any other known report from the National Research Council, Ottawa, or the BBC Research Department; likewise the University of Miami audio faculty or Bell Laboratories, not to mention Los Angeles, New York, Tokyo or Eindhoven locations.

(9) *No Mover-Shakers*. The single consistent source of intelligence in Polarity over the years has been Professor Stanley Lipshitz, of whom more in Section 3. No other individuals have prominently aligned themselves in favor of Absolute Polarity, nor has any identifiable segment of the press (despite occasional lip-service), nor any university or national laboratory. The disinterest shown by these entities helps perpetuate the situation.

(10) *Vocal Objectors*. For all the foregoing reasons, Absolute Polarity remains undeservedly obscure. Nevertheless, a certain contingent denies the very possibility. For whatever motivation they continue to flog the subject, and divide into two camps.

   (a) "Loudspeaker drivers are non-linear in thrust and recede modes, thus accounting for the perceived phenomenon." This argument can be disproved by switching phono-cartridge leads (for instance), to defeat any inherent nonlinearity, and further by playing records cut in opposite polarity.

   (b) "Mass self-delusion," declares Daniel Shanefield [1990 (May)]. Perhaps he meant "massive." Either way, this concept has never been put to the test.

3. SURVEY OF LITERATURE

This author's own high regard for Absolute Polarity arrived many years ago and was acknowledged previously. The frequent reference to 1988 (May) concerns his book, *The Wood Effect*, which deals extensively with acoustic polarity and related topics. Herewith follows an overview of early literature on the subject, condensed from that volume. Readers unfamiliar with Polarity will find the material a valuable preparation for the later experiments; others may skip directly to Section 4.

3.1

In the *Journal of the Acoustical Society of America* (*JASA*) [Sept 1951], Walter Rosenblith and Mark Rosenzweig, working at Harvard's now-dismantled Psycho-Acoustic Laboratory, first revealed that polarity reversal on click impulses altered perception of sound:

> The microphonic component of the [cats' ears] click response reverses when the polarity of the electric square pulse fed into the earphone is reversed (*i.e.*, when a sudden condensation in the auditory meatus is replaced by a sudden rarefaction).

Next, in *JASA* [November 1962] James Craig and Lloyd Jeffress at the Defense Research Laboratory of the University of Texas wrote:

> Auditory theory does not readily account for monaural phase effect (MPE). *Helmholtz's theory certainly did not*, but he avoided the difficulty by denying its existence...The current investigation took its direction from the informal discovery of a new MPE by Charles Wood at the Defense Research Laboratory during 1957. He used as a signal a sinusoid partially clipped during half of each cycle. The resulting sound had a different timbre when the flat-topped portion was presented to the ear as a rarefaction than it did when the headphone leads were reversed and the flat-topped portion was presented as a compression. This attempt to explore the Wood Effect more thoroughly led to the simplified stimulus used in the present study.

That fateful discovery was carefully delineated by David Stodolsky [cited below]:

> The original experiment done on absolute phase shift was reported by Craig and Jeffress. In this experiment, sine waves of 250 Hz and 500 Hz were mixed and presented to the subjects via earphones...A switch was used to invert one signal, which was the same as shifting that component 180^{o}, thereby exchanging rarefaction and compression. The signals were presented for 1 second followed by a 1 second interval of silence and then another tone. The relative phase was randomly varied over 60 presentations and the subjects were divided into two groups on the basis of the subjective differences between the tones. The data

were then analyzed to determine if the presentations were grouped according to phase or randomly. A 90 to 100% consistency was found between grouping and absolute phase.

Meanwhile, the March 1964 *IEEE Transactions on Audio* contained an emphatic editorial by Peter Tappen:

> It ought to be possible [by now] to put together an experimental low-phase-shift phonograph system...One of the first experiments which we believe should be made with such a system, is a determination of the degree of audibility of phase reversal.

A skeptical demurrer from Larry Mertz appeared in January 1965.

> I am puzzled by the editorial on phase distortion. It completely omits any mention of what I had always thought was the crucial consideration. If the amplitude envelope is preserved, then won't the phase distortion be imperceptible?

The editor emphatically disagreed, defining the very basis for this paper:

> What about phase reversal? Here, the phase response is a horizontal line through $\pm 180^{\circ}$. Obviously phase reversal cannot affect the peak-to-peak *amplitude* of the envelope at any instant in time, but, equally obviously, the waveform and envelope are inverted and thus, in general, are different from the original wavefront and envelope. Can this difference be audible in a normal environment? We doubt that anyone knows. We do believe that the answers to these questions might lead to significant advances in the state of the art, and we should like to see some research done on this subject.

Five years' silence ensued on every front, during which the *Transactions on Audio* acquired the tag *and Electroacoustics*, after which came "The Standardization of Monaural Phase" by Stodolsky [Sept 1970]. His compass and range -- with considerably more than Absolute Polarity at stake -- were disclosed in his abstract [emphasis added]:

> This paper redefines and examines the problem of monaural phase distortion in audio systems. Both technical and psychoacoustical aspects of the problem are considered. The redefinition of phase distortion is based upon adopting the acoustical signal at the input of the system as the standard reference. The sources of phase distortion in audio systems are examined with reference to this standard. A review of early and recent psychoacoustic experiments concludes that *monaural phase effects can significantly affect the quality of perceived sound.*
>
> A signal detection model is used to determine a conservative equivalency between frequency dependent phase distortion and amplitude distortion. It is suggested that *a system which maintains a 3 dB tolerance in frequency response should also maintain a* 17° *tolerance in phase shift.* A recent experiment is shown to confirm the conclusion drawn from this model. Absolute

phase (polarity error) is evaluated with reference to amplitude distortion in light of recent experiments. It is concluded that at high sound pressure levels *absolute phase error is more detectable than 11.5% intermodulation distortion*. A set of standards for various types of audio equipment is defined, which if implemented would eliminate absolute phase error in audio systems. Finally, the importance of these findings with reference to realism of reproduced sound is commented upon.

Highlights of this unheeded document are worth repeating here at length [emphasis added]:

> The third source of phase shift we will consider is caused by polarity error. In this case the reproduced wave is either "in phase" or "inverted" in relation to the standard, independent of frequency. In the inverted case the output is an acoustic compression if the input is an acoustic rarefaction and *vice versa*.
>
> In this section, we will present further arguments and evidence to support our contention that monaural phase effects can be significant contributors to degradation of quality in state-of-the-art audio systems. As a result the relevant restrictions on phase error for a given system will become obvious. A standard for frequency-dependent and absolute phase, which will be applicable to all systems of audio reproduction and transmission, will be presented...
>
> In evaluating the importance of absolute phase distortion we will establish a conservative equivalency between this error and a more familiar type of distortion, harmonic distortion. In estimating the equivalence between absolute phase error and harmonic distortion we can rely almost completely on experimental evidence...
>
> As a measure, percent correct is in itself meaningful and it seems that a distortion which made possible distinguishing between original and reproduced sound 94% of the time would certainly warrant investigation, and if possible, correction...
>
> To anyone familiar with modern audio systems technology it should be apparent that even the most conservative equivalent levels of amplitude distortion which we arrived at here have long been surpassed and would not presently be tolerated in high quality systems. Since the correction of absolute phase error is so straightforward and its benefits so apparent, we urge that the solution we propose in the next section be carefully considered. *The importance of absolute phase shift, however, has not been recognized by the engineering community* and it is hoped that this paper will lead to consideration of the problem...
>
> *This paper claims to have derived a relationship which indicates that a serious source of degradation in modern audio systems is present. Why has this source of reproduction error not been noticed and corrected as has been done with other distortions?* As Tappen has commented, "It is doubtful that anyone has ever listened to speech or music reproduced with low-phase

distortion." This combined with the fact that there is less and less listening to "live" music (due both to better reproduction systems and the use of "electronic" instruments and production of electronic music) could result in rejection of phase parameters by the ear-brain system as "useless information." Many of us could have become *phase deaf*.

These observations were inexplicably ignored until seven years later, when Stanley Lipshitz [May 1977], at the University of Waterloo, Canada, wrote to *Wireless World*:

> Here, then, was the explanation of the change in sound quality observed before. It is known from recent work that the inner ear does not respond symmetrically to compression and rarefaction... By switching from "record" to "playback" [in this device] and hence inverting the waveform, the fact that the ear treats compressions and rarefactions unequally results in an audible difference in the tonal quality...This strongly suggests that an effort should be made to standardize the polarities of the whole recording/reproduction chain from microphone, through record or tape, to loudspeaker. It also serves as a warning to those who conduct A/B comparisons on audio components without taking into account the possible relative polarity reversals which components can introduce.

Dr. Lipshitz followed up with a forceful letter to *HiFi News & Record Review* [Jan 1978]:

> I am encouraged to see that Mr. Peter Walker's amplifier comparison challenge has been taken up by at least one person. There is, however, a condition which no one has mentioned so far, which I believe very strongly must also be satisfied in any such test in order to yield valid conclusions. This is: the components being compared must be connected in such a way as to ensure that there is no change in the polarity of the acoustic signal when the switching is performed.
>
> This caution is necessitated by the fact that some amplifiers are inverting from input to output, while others are non-inverting. Mr. Walker's transistorized power amplifiers fall into the former category, while the majority fall into the latter category. Our experience here indicates that audible differences between components can be introduced by failing to take polarity into account. Differences between components can frequently be greatly reduced, or even eliminated, by ensuring that acoustic polarity is maintained when switching from amplifier A to amplifier B.

Later that same year he appeared in *The Audio Amateur* [1978/3]:

> Our experience here indicates that the effects of a polarity inversion can explain most of the audible differences quoted above ...I believe that failure to maintain polarity is one of the most serious shortcomings of A/B tests and one of the main causes of audible differences between components...We have found that polarity reversal affects precisely such subjective aspects as

image definition and resolution, separation of the images from the ambience, and the "rightness" or "realism" of the sound picture.

This view was soon corroborated by Dr. Richard Greiner [March 1979]:

> Audiophiles have known for years that when viewing the output of a record on an oscilloscope some passages of music have a distinctly non-symmetric appearance...It seems reasonable [to suppose] that only one direction or polarity will be correct when such asymmetrical signals are being produced...There is a difference in the sound when the polarity of the signals is reversed...
>
> I believe that sound reproduction...is better when the polarity of instruments is such that [positive] asymmetrical spikes are reproduced as forward motions of the loudspeaker cones ...Loudspeaker polarity should be switched to give the correct final [absolute] polarity...
>
> Perhaps we will one day see standardization of polarity. This would be a good idea for getting the very highest and most consistent quality.

In September 1979 Dr. Richard Heyser wrote to similar effect in *Audio*:

> I propose that polarity convention of every part of the audio chain be identified and this information made available to establish the net polarity of the reproduced sound relative to the original performance...There is truly no aspect of the audio industry that lies apart from this first step into providing information relating to better sound.
>
> I propose that from this point forward the entire audio industry take a basic step which is capable of improving the quality of the listening experience without adding any cost to that product...With constant improvement in audio systems we have now reached the state where many persons can readily perceive the coloration caused by improper polarity in the reproduced sound... Aware of the distinct audibility of polarity, I have since 1974 measured and provided a standard for the phase reference of loudspeaker reproduction, the so-called absolute phase...
>
> I now publicly call upon the entire audio industry, from computer composer through loudspeaker and headphone manufacturer, to acknowledge polarity as a psycho-acoustic parameter and identify either the polarity or phase convention of their product.

Shortly later, *Recording Engineer/Producer* [December 1979] published a corroborative article by Peter Butt entitled "A Fuss About Plus":

> The matter of the audibility of the absolute polarity of audio signals has been on my mind...The basis of this article is the assertion that absolute polarity is definitely not only audible but necessary to the achievement of a realistic acoustic experience of recorded sound. Because of the semantic confusion caused by the interchangeable use of "phase" and "polarity" in general usage...we are presented with a situation where polarity has been lost in a forest of phase...The importance of polarity

as a separate and distinct property from that of phase has only recently risen to general notice.

> Our goal is to reproduce the effect of live performance...It should not be unexpected that acoustic impulses that are observed as compressions in live performance should optimally be reproduced as compressions. It is likewise reasonable that live rarefactions also be reproduced as rarefactions, not the other way around...
>
> The better the reproduction system, the greater will be the difference. The listener will have a clear preference for a recording as heard with one polarity over the other...If accuracy of reproduction is desirable aesthetically, polarity would seem to be a non-trivial matter.

Affirmation arrived soon thereafter from Edward Long [February 1980] in *Audio*:

> Since almost all sounds in nature are unsymmetrical, that is, the pressure variations around the normal ambient pressure may not vary up and down equally over the period of the sound, then this should be taken into account in any good sound-reproducing system. It turns out that a reversal of the polarity of reproduced sound opposite to that which it had in nature is clearly audible. Neglecting this fact has often caused judgments to be made as to the quality of reproduction which were erroneous, and this has been particularly true about judgments concerning the differences between sound-reproducing components. From our experiments over the past number of years, it also appears that listeners have no difficulty in determining the exact polarity which is the same polarity of natural sound.

In July/August 1981, AES members were informed of an Ad Hoc Meeting on the Formation of an AES Technical Committee on Audio Polarity, including Messrs. Lipshitz, Heyser, Butt and Long themselves. The report began:

> An ad hoc meeting was held during the 69th Convention in Los Angeles to consider the formation of an AES Technical Committee on Audio Polarity. The attendees expressed concern that polarity is an important audio parameter and they indicated their interest in active participation in such a technical committee.

Their goals (in part) were:

(1) to summarize and report on existing definitions for reference polarities for all audio systems;
(2) to summarize and report on measurement systems for these polarities;
(3) to summarize and report on current polarity practices.

Despite manifest good intentions, the Ad Hoc Meeting was apparently adjourned forever, judging by its subsequent absence from *JAES*. The next mention of polarity reversal in *JAES* came again from Professor Lipshitz, joined by J. Vanderkooy and M. Pocock [September 1982], in "Audibility of Midrange Phase Distortion in Audio Systems":

> Let us proceed to produce a [two-tone] pattern which is markedly asymmetrical positive to negative, and compare the sound quality when the acoustic polarity of this signal is reversed, by reversing the polarity of the connections to *both* earpieces simultaneously...
>
> This experiment can be repeated on different headphones, and also on loudspeakers, and the effect will still be found to be audible, although not as clearly so on loudspeakers unless conducted in an anechoic chamber, due to standing waves in the room.
>
> In this connection it is interesting to note that not all transducers are of the same acoustic polarity, that is, not all produce an acoustic compression in response to a positive going electrical signal. The original Quad ESL, for instance, is polarity-inverting...This experiment also suggests that an acoustic polarity inversion may be audible on music and speech and this is indeed true...
>
> The authors have demonstrated the two-tone experiment described above to numerous people on different systems. No one has ever failed to hear the timbral change with phase, or discern polarity reversal on the signal. Indeed, in a double-blind demonstration, the accuracy score was 100% [on a two-tone test] over loudspeakers, and over-all, including musical excerpts, the results on the audibility of the polarity inversion of both loudspeakers represented a confidence of more than 99% in the thesis that acoustic polarity reversal is audible.

The most recent reference to Absolute Polarity located by the author in *JAES* occurred in "Time Correction of Anti-Aliasing Filters Used in Digital Audio Systems," by John Meyer [March 1984], in which certain anomalies that reduce phase perception were addressed:

> We have found that given a time-corrected recording and reproducing system, absolute polarity is clearly audible and the difference in sound quality, when the polarity of both channels is reversed, is striking. This would seem to reinforce the argument for the standardization of absolute polarity throughout the recording and reproducing chain, and for maintaining absolute polarity in recording.

There this summary overview of the literature rests. A longer and perhaps exhaustive survey is found in Reference 1988 (May); all but four entries there attest to the obvious audibility of polarity. For ready reference, Appendix A contains every source cited therein, in addition to those herein. *In toto* they constitute a formidable proof of Absolute Polarity, apart from any experiments.

3.2

Numerous anecdotal sources offer testimony as well. For instance, manufacturers' instruction booklets:

> *Mark Levinson*: In the "180" position, the output signal has been inverted, enabling the listener to optimize the sonic performance for each selection.
>
> *conrad-johnson*: Each component in the stereo system is either phase correct or phase inverting. This is of no consequence, so long as the system as a whole is "phase correct" [with respect to music].
>
> *NAD*: **Phase Invert**. This button inverts the polarity, or absolute phase, of the audio signal in both channels. (This is not the same as the relative phase inversion of one channel that occurs when loudspeakers are wired out-of-phase.) The "correct" polarity will depend on the polarity of recorded signals. Polarity inversions may occur throughout the audio recording and playback process -- in microphone wiring, tape recorders, equalizers, CD players, and amplifier circuits. With some loudspeaker systems and some recordings, polarity inversion may produce a change in timbre, a difference in the impact of transients or an improvement in stereo imaging. If polarity reversals are audible in your system, you can use the Phase Invert circuit to optimize the playback of each recording.
>
> *VMPS*: The question arises as to why polarity inversion effects were never before apparent in normal listening. One reason is that, until very recently, phase incoherence in loudspeaker design was the rule. Indeed, even today [circa 1986] approximately 90% of all commercially available speaker systems are phase incoherent, and many feature drivers which are out-of-phase (180^{o}) relative to the rest of the system, or utilize phase-incoherent high-order crossover networks which allow phase to vary in an extremely non-linear fashion over the music spectrum. The effects of inverted polarity are masked by these systems, since their phase response is always incorrect no matter with which polarity they are hooked up.
>
> *Counterpoint*: Absolute Phase Distortion occurs when some amplifier or transducer in the record/playback chain swaps the positive half of the waveform with the negative portion. Thus an instrument that might originally have produced compressive peaks will be produced with "decompression" during playback.
>
> *Theta*: It is unfortunate that many record companies pay no attention to absolute phase. A little experimentation will show the gains: better-defined, more energetic bass and more stable imaging.
>
> *Vandersteen*: It is strongly suggested that you also consider absolute phase, as it may vary from album to album...It may be necessary to reverse connections on both speakers for each record to sound correct.

> *Sound Storage Records*: Another factor that will affect the sound of a system is the absolute phase of the final sound pressure from the loudspeakers...**The only way to determine correct polarity is to listen.**

3.3

In conclusion, Richard Greiner recently addressed the topic again[3] and illuminated the complexity of instrumental asymmetry (quoted here in personal correspondence):

> All instruments make compressions and rarefactions of course. But some make asymmetrical spikes of compression and some spikes of rarefaction. In fact the same instrument makes spikes of one polarity when played in one manner and the opposite when played in another manner. Softly played tones generally show little asymmetry. Interestingly, plucked or hammered instruments do not necessarily show asymmetry even during the initial transient. Of course some do, like the strong drum beats. This makes the situation very complex.
>
> Regardless of the original polarity of asymmetrical spikes and if in fact they exist at all, it is my firm belief that the original temporal waves of compression and rarefaction as picked up on the recording microphone should be reproduced at the loudspeaker.
>
> It is possible to hear polarity inversion of the reproduced acoustic signal in most cases. However, it is not evident that the mechanism by which polarity is audibly distinguished is due to asymmetry of the signal alone or by some much more complex hearing mechanism.

There lies another good direction for future research. It now only remains to promulgate the exquisite perception first given to Charles E. Wood in 1957, affirmed by Tappen and Stodolsky in the *IEEE Transactions on Audio* and reaffirmed later by Drs. Lipshitz, Greiner and Heyser and many others: Absolute Polarity exists and should be perfectly audible.

4. TESTS OLD AND NEW

Successful tests for Absolute Polarity have been conducted and reported already, so the intent here is not to retread old tires but rather to cover new ground. A novel and perhaps more persuasive procedure has been devised involving minimal interference with listener performance. But first we shall consider the previous test menu.

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[3]"Some Observations on the Audibility of Acoustical Polarity Inversion," *AES* Preprint.

4.1 Unblind Tests

The author has experimented unblindly on himself in many various ways, always proving to be an excellent subject. For instance, the oenological experience gives much to reflect upon about tests and trusting one's own judgement. In this regard, some quotations from Michael Polanyi's *Personal Knowledge: Towards a Post-Critical Philosophy* may not be remiss. Herewith a few samples, with respect to audio and acoustics, from this fine book on epistemology:

> I hold that the elimination of personal knowledge from science would destroy science...Formal operations relying on *one* framework of interpretation cannot demonstrate a proposition to persons who rely on *another* framework. Its advocates may not even succeed in getting a hearing from these, since they must first teach them a new language, and no one can learn a new language unless he first trusts that it means something...
>
> The refusal to enter on the opponent's way of arguing must be justified by making it appear altogether unreasonable. Such comprehensive rejection cannot fail to discredit the opponent. He will be made to appear as thoroughly deluded. Every great scientific controversy tends to turn into a dispute between the established authorities and a "pretender" who is as yet denied the status of a scientist, at least with respect to the work under discussion...
>
> A hostile audience may in fact deliberately refuse to entertain novel conceptions. Those who listen sympathetically will discover for themselves what they would otherwise never have understood. Such an acceptance is a heuristic process, a self-modifying act, and to this extent a conversion. It produces disciples forming a school, the members of which are separated for the time being by a logical gap from those outside it. They think differently, speak a different language, live in a different world, and at least one of the two schools is excluded to this extent for the time being (whether rightly or wrongly) from the community of science.

Thus does Professor Polanyi foreshadow the current rift in audio between "objectivists" ("fact") and "subjectivists" ("fantasy") and stand with a foot firmly fixed in either camp! This writer finds all four appellations tendentious and ill suited to an environment of free enquiry, and supposes that were Polanyi alive today he would include the controversy in his next book.[4] The partition strongly suggests an "us" *vs.* "them" mind-set, leading the new school to throw their hands up in despair and disgust

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[4]"Audio Fact and Fantasy: Reckoning with the Realities," theme for the AES 91st Convention.

at their rejection by the establishment. Surely this response is foolish too. Rapprochement may be found in the neutral term "observation," as by eye (meters) and by ear (sound). The latter perceptions, while troublesome to quantify, must not be summarily dismissed. Subjective response, as in unblind tests, at the very least should constitute a fruitful source of hypothesis.

4.2 Single-Blind Tests

This stratagem is often employed (even in the wine world, although more for sport than evidentiary status) to introduce an element of "scientific respectability" to the proceedings. All well and good, because most participants, while highly qualified and devoted to truth, nevertheless are susceptible to various prejudices which, however random, may skew results and leave them open to challenge.

Unfortunately this procedure has some serious side-effects on individuals themselves. Unconsciously reduced to automatons, they become bored and no longer perform as experts. Because they wish to "score" well, stress sets in. But they may not learn the outcome immediately, if ever. They begin to fret about the utility and propriety of it all. These problems, for which no solution yet exists, are subsumed and enlarged by the next level of testing.

4.3 Double-Blind Tests

Individuals (now known as "panelists" or "subjects"), being human and alert, pick up cues from the test administrator, the theory states. Indeed they may, but somehow the corrective measures produce a contest between testers and testees, not a healthy circumstance. Besides, they fail to address the major shortcomings of blind testing, *viz*:

(a) Undefined Limits of Resolution. No evaluation exists, whether such a procedure can reveal the distinctions sought. Indeed the massive null results suggest otherwise.[5] Yet the demand is ever heard for "rigorous double-blind tests" to qualify any step in audio that ears alone

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[5]Null is not negative, although scoffers in the popular press like to think so. *Stereo Review*, October 1990: "Most publicized double-blind tests have turned up no statistical evidence for genuine audible differences between amplifiers."

apparently cannot support, while the process itself has not been rigorously thought out. Consider two curves: the "learning curve" with a positive slope followed by a down ramp, and the "stress curve" with a constant upwards slope. Other things being equal, where do they cross? When are data most accurate? How may that point be isolated? Can "subjects" be humored into a non-stressed condition? Has stress ever been deliberately introduced at the *outset* of tests to determine whether *any* positive results may obtain? Answers to these questions would surely yield great improvements in rigor and resolution.

(b) The side effects occur relatively early, leading to impatience, anxiety and exhaustion. Everyone knows you change when you take a test. Wise wine-tasters anticipate such difficulty and literally spit out the samples, freeing themselves from fatigue by alcohol. In audio, music comprises an intoxicating spiritnd its negative cumulative impact through misuse -- which *cannot* be expectorated -- may explain our natural discomfort with the arduous artifice camouflaged as science under the rubric "double-blind tests."

(c) Poor selection of participants. For whatever reason, "panels" are chosen from a populace largely unacquainted with the phenomenon under test. For justification, an anonymous professor at a respected university has written, "One should conduct [audio double-blind] tests among a population representative of the intended market...the general public...so that the sample group approximates that of the target market." Small wonder so many null results have followed.

Consider the conundrum of how to establish proof for "perfect pitch." The general public here clearly should *not* be relied upon, nor even experienced listeners and musicians, because if you don't have it you can't hear it! Indeed, an ideal test to answer several questions posed above in (a) might be performed on persons with "perfect pitch," to determine how their powers may change under the duress of double-blind methodology.

The fact remains that laymen are elevated to judicial status while no procedure exists to qualify them before they qualify the product. That discrepancy remains unaddressed to date in audio and psychoacoustic testing, yet the clever oenologists have managed to certify Masters of Wine.

4.4 Triple-Blind Tests

To lessen or eliminate several foregoing objections, this study employs the novel device of Triple-Blind, which addresses stress by compelling relaxation. Simply stated, the takers are blind to the test until it is over, which eliminates any atmosphere of pressure. Results presumably become more reliable and more indicative of reality. Exact procedures are outlined in the next section.

5. TEST DESIGN AND PROTOCOL

This paper outlines the first, preliminary approach to Triple-Blind testing. For ultimate authenticity a professional statistician must be engaged, preferably one who cannot hear Absolute Polarity, who can therefore guarantee that no procedural prejudice exists. Even then, should a positive decision be obtained, certain parties will argue that the outcome must be discounted. In short, no amount of expertise applied to blind tests has ever rescued the results from challenge by someone who will not accept the conclusion. Therefore the methodology employed here is deliberately simplified to save time and space and ears while highlighting the innovation of *triple-blind*.

5.1 Site, Set-Up and Sources

Location for tests was The Listening Studio in Boston. While other sites might have served equally well, The Listening Studio has a music reproducer conforming to classic "minimum phase" criteria, especially in loudspeaker design, which is essential to perceive polarity. Indeed, anecdotal evidence gathered over the years shows that many Listening Studio visitors surprise themselves by hearing Absolute Polarity there for the first time. Thus this facility became the appropriate venue.

Sources were LP records exclusively, as the CD medium was found (in collateral, unreported tests) to reveal polarity rather less well. Musical material consisted of simply-recorded acoustic instruments, mostly classical "chamber" and jazz "combo" repertoire, largely bypassing the vagaries of mixing and multi-miking. Also, although polarity is a monaural phase effect, only stereo records were used.

Switching was accomplished by manual reversal of loudspeaker leads at the amplifier end, behind closed doors, totally out of sight.

5.2 Preparation of the Subjects

In contrast to most test situations, personnel here were *self-selected* and *unsuspecting*. The operator conducted "business as usual" with each, helping them become familiar with the room and audio system, so they might enjoy some "home court advantage." The test itself began spontaneously, at leisure, often on a record brought by the subject. The only criterion was that it would commence in incorrect polarity, to simplify data reduction *and* regularize the subjects' experience.

Obviously this concept rests on the operator's ability to identify reversed polarity,[6] as no disc, record or tape carries such designation. Therefore he (the author) volunteers to submit to verification. Moreover, he was prepared to abort any test, should it have developed that he had decided incorrectly.

At this point some remarks from the valuable manual used to guide these tests, Floyd E. Toole's "Subjective Evaluation" as found in the *Loudspeaker and Headphone Handbook*, should be introduced:

> Examinations of listener performance and preferences...indicate that listeners with musical training and considerable regular exposure to live music do not distinguish themselves as being better than, nor necessarily different from, dedicated Hi-Fi listeners...
>
> Naturally, listeners should be discouraged from communicating their feelings during or between tests. Even subtle sounds or actions can be influential, especially from a person whose opinion is respected within the group. The effects of group voting can be eliminated by using single listeners.

(For this reason only single listeners were employed here.)

> Allow for at least one practice round to permit listeners to adapt to the novel listening situation, the music, the room and the questionnaire...
>
> If the listeners have been carefully selected and the physical and procedural factors in the listening test have been adequately controlled, the data that emerge can be used for most purposes

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[6]The audio press has already utilized such a procedure [*Stereo Review*, June 1991]: "A proper double-blind test requires proper equipment and much care in setting it up...Polarity and levels were controlled..." No word was forthcoming on how polarity was ascertained, presumably the operator determined it.

> with very little processing. An arithmetic average of the ratings on each product is sufficient to indicate the relative merits, which is the aim of most such tests...Experimenters interested in more elaborate analysis of test results will find that there are numerous options.

This experiment has opted for the simple approach with minimal processing. To summarize, the subjects should be (and were) familiar with room, gear, music and operator before the test. Under no circumstance was the topic of Absolute Polarity broached, nor of tests, not one hint.

5.3 Test Conduct

Casually, after an appropriate selection had appeared in the course of events, the operator (so as not to cause undue suspicion) winked at the subject and spoke words to the effect, "We'll do that again," then disappeared backstage to the control room. Quickly switching wires, he replayed the same passage (approximately 90 seconds duration) and *stayed out of sight* to fulfill the criterion of a blind (unseen) operator. After the repeat passage was completed, the operator returned to the subject's presence and handed him the response sheet on a clipboard, saying "Did you hear a difference?"

Each test was conducted one-on-one, no audience. One man, one test, period.

5.4 Response Sheet

The response sheet comprised two halves. Each testee saw Part I only after both initial listening episodes were completed, whereupon he learned that this had been a test. Part II was folded underneath for later use. (Parenthetically, the precise wording varied somewhat throughout the procedure while the author fine-tuned the experiment. Responses before a certain point were eliminated simply because the wording was sufficiently different to disinclude them, yet they would not have changed the results!)

5.4.1 Part I

As shown in Figure 1, the first question addresses whether the subject was aware of a test, therefore by implication, whether such knowledge might have influenced the outcome.

The second question asks: *"Did you hear a difference?"*

HELLO! HERE IS AN OFFICIAL SCORE SHEET

PLEASE KEEP FOLDED FOR NOW

"I'm going to play that for you again," I said with a wink. After a pause and a repeat, you were handed this surprise and asked, "Did you hear a difference?" Congratulations! You are participating in a bona fide test.

First, did you feel any noticeable tension or pressure? (Regardless whether you guessed what was happening)
- ☐ No
- ☐ Yes
- ☐ Maybe

And, did you hear a difference?
- ☐ No
- ☐ Yes
- ☐ Maybe

If Yes, would you further say that one instance was better, rather than just different?
- ☐ No
- ☐ Yes

If Yes, which?
- ☐ The First
- ☐ The Second

Again, if Yes, please describe the "better" one briefly.

Finally, how would you categorize yourself?
- ☐ Audio engineer
- ☐ Hi-fi hobbyist
- ☐ Musician
- ☐ Other_____

You may unfold the lower half.

Should you choose to do so, the above experiment will be repeated, only this time with unfamiliar music, and the first episode will be played twice to accustom you, then the "change," if any, will be made.

First, did you feel any noticeable tension or pressure?
- ☐ No
- ☐ Yes
- ☐ Maybe

And, did you hear a difference?
- ☐ No
- ☐ Yes
- ☐ Maybe

If Yes, would you further say that one instance was better, rather than just different?
- ☐ No
- ☐ Yes

If Yes, which?
- ☐ The First
- ☐ The Second

Please describe the "better" one briefly.

Signed (The testee)_____

Date_____

The third inquires whether one example was "better," rather than merely different.

The fourth demands, "If so, which?" This question addresses the heart of the matter, although a positive response to the second would settle whether polarity is audible.

The fifth seeks to differentiate among engineers, hobbyists and musicians in Polarity perception.

5.4.2 Part II

This section, which also underwent extensive evolution, was intended to expand any indeterminate results from Part I. It therefore remained unused, and its explication and execution must be reserved for a future treatise.

6. RESULTS AND CONCLUSIONS

The Triple-Blind listening tests, simple and unstressful, were even easier to analyze than to administer. Part II, envisioned as a more rigorous event to elucidate Part I, proved inapplicable due to consistent positive results already, which also obviated a call on whether the triple-blind feature was useful, or whether musicians could detect polarity better than could audio personnel. These questions must be assigned to future experiments. There was a unanimous positive response to "Could you tell the difference?" and 100% preference (22 of 22) for the second choice (arranged by the operator to be in correct polarity) as the "better sound."

Whatever statistical method employed, these results prove to the utmost confidence level that Absolute Polarity constitutes a fact of life in audio and whoever denies it must engage in fantasy. Witness the written testimony on response sheets regarding the improvement:

- more clarity, greater focus
- tighter bass
- better bass resolution, crisper transients
- more airy, changed from sucky to punchy
- more clarity and focus, music coming *towards* me
- went from muddy to phase-aligned
- sound stage opened up, less localized to speakers
- like a towel being lifted off
- greater impact

- more music

The conclusion becomes inescapable: Absolute Polarity is ignored only at great peril. The "muffling distortion" afflicts every application of sound reproduction: phonographs, cinema, concert reinforcement, broadcasting, hearing aids. Moreover, many previous experiments in audio, acoustics and psychoacoustics must be re-examined, wherever polarity was disregarded, for an overlay of this random distortion would seriously have compromised the results.

Any attempt to minimize the consequences was contradicted long ago in Reference 1970 (Sept), where we have already read:

> Absolute phase error is more detectable than 11.5% intermodulation distortion...it seems that a distortion which made possible distinguishing between original and reproduced sound 94% of the time would certainly warrant investigation...The importance of absolute phase shift has not been recognized by the engineering community...[Why?] Many of us could have become *phase deaf*.

We may well wonder why such a powerful tool as Absolute Polarity remains obscure. Perhaps its very simplicity mitigates against it, in a world grown increasingly used to complex solutions. And almost unbelievably, it costs next-to-nothing to fix. This study should, at the very least, inspire attempts at corroboration and affirm minimum-phase design criteria in loudspeakers. Impetus should also be given to standardization of component polarity, which would seem to be "a good idea" until everyone can *hear it for themselves*. Finally, one may hope for permanent eclipse of the attitude portrayed in the opening Abstract: "Absolute Polarity is an interesting phenomenon [wherein] those who don't hear the effect mostly doubt the opinion of those who do."

Appendix

Chronology of Printed Reports about Absolute Polarity

1951	(Sept)	Journal of the Acoustical Society of America, Rosenblith and Rosenzweig, "Electrical Responses to Acoustic Clicks: Influence of Electrode Location in Cats."
1962	(Nov)	JASA, Craig and Jeffress, "Effect of Phase on the Quality of a Two-Component Tone."
1964	(Mar)	*IEEE Transactions on Audio*, Peter Tappan, "Phase Distortion."
1965	(Jan)	IEEE Transactions on Audio, Larry Mertz, Peter Tappan, "More on Phase Distortion."
1970	(Apr)	JASA, Don Ronkin, "Monaural Detection of a Phase Difference between Clicks."
	(Sept)	IEEE Transactions on Audio, David Stodolsky, "The Standardization of Monaural Phase."
1972		Spatial Hearing, Jens Blauert
1974		JAES, Hansen and Madsen, "On Awal Phase Detection."
1977	(May)	Wireless World, Stanley Lipshitz, "Audibility of Phase Effects."
1978	(Jan)	Hi-Fi News Record Review, Stanley Lipshitz, Letter.
	(M/J)	The Audio Amateur, Stanley Lipshitz, Letter
1979	(J/F)	TAA, Jung and White, John Curl, Letters.
	(Feb)	Recording Engineer Producer, Peter Butt, Letter
		International Audio Review Journal 4 Peter Moncrieff, Phase Distortion."
	(Mar)	Boston Audio Society Speaker, Richard Greiner, Letter.
	(IV #5)	Stereophile, J. Gordon Holt, Review.
	(Sept)	Audio, Richard Heyser, "Polarity Convention."
	(Dec)	Re/p, Peter Butt, "A Fuss about Plus: Preservation of Audio Signal Polarity."
1980	(Feb)	Audio, Edward Long
	(M/J)	TAA, Stanley Lipshitz, Letter.

(M/J) Fanfare, Neil Levenson, "For Audiophiles."

IAR Journal 5, Peter Moncrieff, Review.

Sound Storage Records, Notes.

(Oct) Stereophile, J. Gordon Holt, Review

(Nov) HFN/RR, John Atkinson, "Listening Tests and Absolute Phase."

1981 (Jul) JAES, Ad Hoc Committee Report.

(Sept) The Absolute Sound, Tutay and Pearson, Letter and Response.

1982 (Mar) TAS, Pfeiffer and Pearson, Review.

(Apr) IAR, Peter Moncrieff, "Polarity in Head Amps."

(Jun) TAS, David Wilson, Review.

(Sept) JAES, Lipshitz, Pocock, Vanderkooy, "Audibility of Midrange Phase Distortion in Audio Systems."

1983 (Jan) Audio, Sam Burwen, "Confessions of a Digital Recordist."

(Mar) Audio, Bert Whyte, "Behind the Scenes."

(Apr) Re/p, John Roberts, "Exposing Audio Mythology."

(Jun) JAES, Dan Shanefield, Letter.

(Sept) HFN/RR, Stanley Lipshitz, Letter.

1984 (Jan) Fanfare, Al Fasoldt, "The Common-Sense Audiophile."

(Feb) Audio, Len Feldman, Response to Letter

(Mar) JAES, John Meyers, "Time Correction of Anti-Aliasing Filters Used in Digital Audio Systems."

(Mar) Fanfare, Neil Levenson, "For Audiophiles."

(Apr) TAS, Harry Pearson, Footnote.

Re/p, Stephen Temmer, Letter.

1985 (Jun) HFN/RR, Ken Kessler, "Phased and Confused."

(Jul) TAS, Enid Lumley, Column.

(Aug) IAR, Enid Lumley, Column.

HFN/RR, Atkinson, Marshall, Fox

Stereophile, Holt, Archibald.

(Sept) HFN/RR, David Hart, Letter.

(Oct) Stereo Review, Ralph Hodges, "Absolute Phase."

1988 (May) The Wood Effect, R.C. Johnson

(Jul) High Fidelity, Larry Klein

(Sept) Stereophile, John Atkinson, Review of The Wood Effect.

(May) Stereophile, Dick Olsher, "An Absolute Sidebar."

(May) Stereo Review, Julian Hirsch, "Is Polarity Audible?"

(J/A) 21st Century Science and Technology, David Shavin.

Speaker Builder, John Cockroft, Review of The Wood Effect.

(Aug) Audio, Edward Long, Review of The Wood Effect.

(Sept) Stereo Review, Ian Masters.

(Oct) Stereo Review, Julian Hirsch, "Polarity Revisited."

(Nov) Stereo Review, Ian Masters.

(Dec) Audio, Review of "Apogee Duetta."

1990 TAS, Frank Doris, "Sidebar."

(M/A) TAS, Ben Holt.

(Mar) Audio, Joseph Giovanelli, Audio Clinic.

Audio, Letter.

(May) Audio, Dan Shanefield, Letter.