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The Superiority of Analog Audio Tape Recording vs. Digital Recording.

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Today he works as a free-lancing consultant, runs an electronics design lab and owns a GmbH. He has about 40 yrs. of continuous experience with magnetic tape recording, audio and video;
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Summary:

Unexcelled for audio quality, reliability and longevity, proven over more than 50 years, the superiority of analog tape recording over any other recording method remains firmly established. Digital processing suffers from a multitude of technical problems, the reliability and longevity of digital recording media is at best questionable and sofar unproven.

1. Introduction.

The term „digital“ is believed by many to be synonymous to „superior“. Digital may be modern, digital recording media are less expensive, smaller, lighter and easier to handle, but regarding quality and longevity digital is inferior

Analog audio signal processing and recording was and remains superior to any digital method. This applies especially to analog magnetic tape recording. The many and serious problems of digital processing and recording are known to experts but are rarely published other than in strictly professional media like the „AES Journal“. He who is interested is invited to obtain the AES test CD „Perceptual Audio Coders: What to listen for“.

Not surprisingly, on the recent HiFi exposition „High End“ in Munich, there were tube amplifiers and record players all over, in nearly all hearing demonstrations only records were used. It should be remembered that nearly all records are made from analog tape recordings.

2. Reliability and longevity of recordings.

In the author's opinion the reliability and longevity of recordings is by far the most important issue. This is easily understood if we just assume all historic recordings were made on CD's. Audio experts knew it all along, but meanwhile the truth can be read in newspapers, it became a nightmare in archives: many CD's deteriorate, often within a few years, some within days. Due to the fact that the recording will be totally unusable as soon as the error correction can not any more compensate for data loss, the recording will be totally lost ! We would never be able to hear Furtwängler, Walter, Toscanini etc. had they been recorded on CD's! So let us be grateful and pay due credit to records and tapes which play even after 50 or more years like on the first day.

The DVD is too young so there is no experience, but, due to their higher storage capacity, they will probably be more prone to data loss. As the DVD is already being replaced by „blue ray" DVD's which will in due course be replaced by „violet" and these by „ultra violet" etc. DVD's, there will never be time to collect sufficient data about long-term performance. The extremely short life of all digital standards proves that their proponents are the least interested in longevity.

The only audio recording media with proven reliability and long-term performance were and are records and tapes.

Analog magnetic recordings will last as long as the tape lasts mechanically and chemically, the recording itself does not deteriorate, print-through may increase somewhat. In the past, there have been problems with some tape formulas, all tape manufacturers were affected: the coating may shed, rub off onto the heads and tape guides, also the base material can deteriorate. The problems and solutions are understood. The requirements for analog tape storage are by no means stringent: a plastic bag and avoidance of high temperatures and moisture as well as fast transitions. A clearance of appr. 10 cm will protect tapes from most ubiquitous sources of magnetic fields. There is no reason why tapes should not last hundreds of years, that is tapes on suitable base material. The author owns tapes which are more than 50 years old which withstood 5 household moves including overseas shipments and are still immaculate.

Digital magnetic recordings require a sampling frequency which must be about five times higher than the highest signal frequency. Consequently, the wavelengths of the recorded digital signals are shorter by the same factor, the recordings are in the submicrometer range, i.e. they reside just on the very top surface of the magnetic medium; any minor mechanical defect will cause data loss. This is in sharp contrast to analog recording where the wavelengths correspond directly to the signal frequencies; low frequencies will magnetize the whole depth of the magnetic layer, a mechanical surface damage would only affect the higher frequencies, the recording will never be lost, it may be impaired.

Attention should be drawn to an important fact: Storing digital recordings in archives makes only sense together with a playback apparatus. While a tape recorder can be easily built or repaired any time now and in the future from standard mechanical and electronic components, it will be impossible after a few years to get replacement parts for any digital playback machine, they contain special components like custom ic's which can not be replaced by anything else: if this machine becomes defective, one can only throw it away and all digital recordings after it! This is why owners of digital recordings are continuously forced to transfer all their recordings to the next „new" digital format. As soon as they would stop transferring all recordings would be lost!

In sharp contrast to this: the standards of analog recording on tape and disc have not been appreciably changed for decades: any 50 year old tape recording at 19 cm/s or more or disc can be played on any recorder/player; this is an advantage which can hardly be overestimated. Very old tape recordings can be played, too, they will only require some low or/and high frequency response adjustments.

3. Basic facts about digital processing.

There are very many reasons for the „harsh digital sound“, a comprehensive treatment would require at least 50 pages.

1. Digitizing implies loss of information which can never be recovered: any detail smaller than the LSB is lost.

2. There is no such thing as just digitizing: it is seldomly realized that a/d conversion requires previous sampling and subsequent d/a reconversion, hence any digitized signal will suffer from the **combined** problems and faults of all **three conversion steps**!

3. Hardly ever is it recognized or mentioned that any digitized signal will be distorted the more the smaller it becomes, if it becomes very small eventually only the LSB will be switched on/off, i.e., one gets a square wave entirely independent of the original waveform. Thus e.g. the 16 bits of the CD look impressive only at first sight, in reality the lowest 10 bits can not be used if one wants to avoid too heavy distortions in the a/d process; 6 usable bits remain which is anything but impressive as this amounts to just 64 : 1 or 36 dB. And this explains why practically all digital recordings, broadcasts even of classical music etc. are more or less strongly compressed and squeezed into these 36 dB - with disastrous effects; this creates a completely unnatural, unbearable picture of the music.

   The „low noise“ of the CD comes about because the players set the output to zero if the signal becomes too low; this is logical: better zero than strong distortions of low signals.

   While the distortions in digital processing and recording **increase** with decreasing signal amplitude it is just the opposite in analog processing and recording: the distortions **decrease** with decreasing signal amplitude! **Fine musical detail is hence mutilated or lost in digital processing but preserved with analog processing**. This is one major reason for the superiority of analog processing and recording.

   When the CD was introduced, its „superior dynamic range 100 dB“ was touted; funny enough, the proponents of digitized audio found it later necessary to go to 20 and even 24 bits which should be highly superfluous. Apart from the basic fact that 24 bits can not be realized unless averaging for days is used, this proves the point: the lowest 10 bits being unusable there will remain 14 bits which amounts to 84 dB. This looks more than the best tape recordings can achieve, but all the other problems of digital recordings remain. The proponents of 44.1 KHz also had to admit that 192 KHz indeed sounds clearly better.

   In digital recording practice, a substantial safety margin resp. headroom must be observed because any digital system causes hard limiting, hence the theoretical dynamic range can not be fully used. So in practice even 24 bit systems do not offer more dynamic range than a modern tape on an adequate recorder because the tape saturates softly.

   Note that the dynamic range of a tape is given with respect to the reference level, but a tape such as SM 900 exceeds this by 15 dB so about 75 dB are attainable, unweighted, of course. Subtracting 10 dB reserve from the 84 dB results in the same figure.

4. The digitizing process itself suffers from a multitude of a/d converter problems which cause distortions. The 3-step digital processing creates distortions and artifacts which are not harmonically related to any signal frequency and thus are considerably more objectionable than harmonics. Digital Storage Oscilloscopes suffer from the same problems, there the distortions and artifacts are visible.

5. Sampling requires the observation of physical laws, otherwise severe distortions and artifacts will arise. The Nyquist theorem is mostly misinterpreted with the consequence of false decisions: one case in question is again the CD: the 44.1 KHz sampling frequency is entirely insufficient, the bare minimum for any digitized audio ist 96 KHz. The factor of 2 is pure theory. Pulse fidelity must be preserved which is impossible if too low a sampling frequency requires steep low pass filters which cause severe transient distortions, these add to the distortions of the digital processing and contribute substantially to the „harsh digital sound"! The Nyquist theorem assumes the existence of a socalled brick-wall filter which can neither be realized nor would it be acceptable. The sampling frequency must be at least 5 times higher than the highest frequency in the signal in order to allow for filters which attenuate signal frequencies sufficiently in order to prevent aliasing while preserving signal fidelity. Often the term „oversampling" is used, this is a misnomer, it is „just sufficient sampling".

6. The d/a reconversion never delivers the true signal but only a more or less accurate reconstruction. Often interpolation between sampling points is used, this causes additional severe distortions if there are too few samples. The Nyquist theorem yields only two samples per signal period, any waveshape may be drawn through these two points! A reconstruction is only possible because Nyquist implies previous knowledge of the signal waveform: it is a sine wave. This is easily and convincingly demonstrated on a sampling scope.

7. Recording 2 channels at 192 KHz with 24 bits yields such amounts of data that „data reduction" is mostly used, especially if music is sent via the internet. All these schemes mutilate the music: broadly speaking only the envelope is left over, the details are discarded. Splitting the frequency range into a multitude of small bands, similar to what some „noise reduction" systems do, and processing them differently with later recombination will never allow to restore the original signal waveform. A Fourier amplitude spectrum can be derived from a signal, but the signal can not be reconstructed from this spectrum because the phase relationships were lost.

8. Digital processing resp. recording has advantages: no crosstalk in multichannel recordings, no print-through, no loss of dynamic range with increasing frequency, lossless copies, a CD or DVD is lower in manufacuring cost, smaller, lighter, easier to handle, playing a CD or DVD does not (?) deteriorate the recording. However, a tape recording does not deteriorate either if the recorder is in proper state, a record does, but if it is played „wet" which is mandatory for noise and distortion reasons the wear will be neglegible. In practice only the handling advantages are left.

3. Basic facts about analog processing.

1. With analog processing no information is lost, the smallest usable signal is in principle defined by the noise floor of the system, but it is not that simple: even small signals are still discernible in the presence of noise because the ear easily discriminates. The largest signal is defined by the dynamic range of the system.

2. As mentioned the distortions in analog systems are nearly zero for small signals and increase with the signal amplitude; this suits the logarithmic response of the ear because subtleties and fine detail are preserved while at high levels the ear causes distortions itself.

3. Distortions in analog systems create only harmonics and intermodulation related to the signal which are only moderately disturbing.

4. Analog processing depends on the properties especially of the active components: bipolar transistors and ic's cause a multitude of distortions the worst being thermal distortions. This is why tube amplifiers abound in hifi equipment; they remain unmatched for linear amplification. Their only fault is the slight curvature of the characteristic which causes some low harmonic and intermodulation distortion. The famous conductor Eliahu Inbal once called the distortions caused by transistor amplifiers „Electronic garbage."

3. Analog tape recording.

1. Far and away most of the progress in analog tape recording was contributed by the dramatic improvements of the tapes. Fine-grain particles of high coercivity, high packing density and a super-finish surface combined yielded tapes of truly superior quality which allow hifi recordings from 9.5 cm/s.

2. The analog tape recording process is as yet not fully understood. It is a sampling process because the bias field is about ten times stronger than the signal field, the signal is hence only recorded whenever the bias field crosses the socalled critical field strength, i.e. it is sampled with the bias frequency. Consequently, the same requirement for a sampling frequency of at least 5 times the highest signal frequency exists as well as the requirement for an antialiasing filter between the recording amplifier and the record head which very few recorders have. In the fifties a Telefunken KL 35 recorder used already 126 KHz, obviously those engineers knew more than the inventors of the CD decades later. Good recorders use 125 to 250 KHz. Older recorders which often had iron erase heads used down to 40 KHz, and the aliasing products were clearly audible.

3. Analog recording is a highly linear process, however, the depth of recording depends on the wavelength, i.e. the signal frequency at a given speed. The recordable level decreases with increasing frequency; luckily this is in line with the spectral content of most of the music. At very high levels of recording the highest frequencies may be attenuated depending on the tape, the bias and the wavelength, i.e. the speed. The high levels of the low frequency components of the signal may then modulate the high frequencies‘ amplitudes.

4. Modulation noise depends strongly on the tape and head surfaces, the tape’s mechanical properties and the quality of the tape drive system, i.e. the recorder and the tape should match.

4. „Noise reduction“ systems‘ drawbacks.

The noise in tape recording increases with decreasing tape speed and track width. The recording standards are similar to those of records, i.e,. high (and in semi-professional and amateur recorders also the very low) frequencies are boosted and attenuated during playback. As a compromise had to be found between the loss of dynamic range and noise reduction, methods were developed to abate the noise. The simplest methods just use level-dependent high frequency boost, this is acceptable for cassette recorders. More sophisticated methods separate the frequency range into several bands and process each band independently. All these methods adversely affect the signal and should be absolutely shunned for high quality recordings, with modern tapes and from 9.5 cm/s they are unnecessary.

5. Tape recorder problems and requirements.

The performance of modern tapes exceeds the abilities of most tape recorders, this is a matter of serious concern.

This is aggravated by the fact that, as a rule, older tape recorders will be defective. Thus the results of using a tape on an inferior or/and defective recorder may be disappointing. This issue is further complicated if such tests are performed using music from digital media. Only live recordings or music from tapes or records are good enough, and it should be checked that neither a „noise-reduction“ system nor any digital processing interfered and that no compression was used. Also a tape recording can only be properly judged if the power amplifier and the loudspeaker match in quality, and this means tube amplifier and preferably an electrostatic loudspeaker or a professional headphone like the AKG K 1000.

1. Modern tapes like the RMG SM 900 accept signals up to 15 dB above reference level which is far above the capabilities of most recorders. The tapes can be used, but the recorder sets the limit of the attainable dynamic range.

2. Further, full use of the tapes‘ high quality requires that the recorder was properly adjusted, mechanically and electrically, that the heads and tape guides are not worn or dirty and that they were demagnetized. This requires a calibration tape and a symmetry tape.

3. For all measurements and adjustments only an analog oscilloscope should be used, no voltmeters or the like. Only a scope will show the signal clearly separated from noise and residual bias signal, voltmeters measure the average or rms of all, such that erroneous figures result, especially for the signal-to-noise ratio.

4. Tape noise has a variety of causes, only some of which are due to the tape. On a suitable machine modern tapes like RMG SM 900 or 468 can be used even at 9.5 cm/s with neglegible noise. The tape transport system and the head construction are prime causes of excess noise because any mechanical vibration of the tape at the recording head will record.

5. Recorders which contain integrated bipolar amplifiers are unsuited for quality recordings because those cause distortions.

6. All recorders contain electronic components such as electrolytic capacitors which age and change their properties drastically, eventually completely opening up. In the first place such capacitors must not be used in the signal path because they cause distortions, but this is predominantly the case in all recorders with semiconductor electronics. Consequently, any recorder older than appr. 5 years should undergo a thorough restoration of its electronics and mechanics and a complete readjustment before any high quality tape is used on it. If the capacitor preceding the recording head should leak, high tape hiss and distortions will result. The Agfa Symmetry Tape is the best means to detect such problems. Its output signal must remain < - 50 dB, otherwise the recorder is inadequate; few recorders will pass this test! Good recorders have an adjustment for zero symmetry tape signal; due to the earth field this adjustment remains only perfect if the orientation of the recorder is not changed.

5. Poorly designed bias generators are an often unrecognized cause of tape noise, distortions and loss of dynamic range, and such abound in very popular recorders which are advertised and believed to be professional or semi-professional! Also here the Agfa Symmetry tape will uncover such problems relentlessly.

6. It is known that the tape heads, guides etc. must be regularly demagnetized with a suitable choke. However, the heads can be magnetized by switching transients and also by overdriving the recording amplifier, depending on its design. Hence it is necessary to check with the Agfa Symmetry tape whether the recorder is in order before any test recording or other important recording is to be made; after the test the recorder is better not switched off and on unless it was checked that this does not cause magnetized heads.

7. Due to their steep characteristic the sensitivity of modern tapes is very high, this entails that stray fields from the earth, drive motors, the mains transformer etc. will be recorded. It is absolutely necessary to also shield the recording head; this is known since Dr. Krones of Agfa wrote his famous and still unsurpassed articles, but very few recorders have such shields. It is recommended to reread his articles.

8. Mechanically or electronically controlled constant tape tension is mandatory, but many popular professional or semi-professional recorders lack this.