What is Analog?
Can I eat it?

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Abstract

There is nothing new about analog or about how yummy it is. However, it is now coming back to the mainstream as a trend, after decades of relative obsolescence. The younger generation that did not grow up with it are often confused about what it really is. Several myths have developed and it seems that even the older generations are starting to forget, what analog really is about. This text will attempt to set the record straight.

Preserving the entire wave and not just droplets of water

Analog, when referring to audio, describes the audio electronics and storage media, that can process, store and reproduce the entire signal, as opposed to sampled parts of the signal which is what we call digital.

If we use a violin as an example, being an acoustic instrument, it creates changes in air pressure when played. A microphone placed near the violin would convert these into an electrical signal, which would represent the entire movement of the air waves. Now, to make it easy, let us assume that this violin is producing a pure 1 kHz tone. The microphone would convert this into a 1 kHz electrical sine wave, which is an almost perfect representation of the original sound. In the analog realm, the microphone preamplifier, mixing console, any other processing units, the recording and the reproduction equipment would all deal with this entire sine wave without converting it to anything that no longer looks like a sine wave.

In the digital realm, there is no digital piece of equipment that can deal with this entire sine wave. For a signal to become digital, it needs to be sampled. Sampling is the process during which the original sine wave is broken up into a series of dots/samples, taken at regular intervals, capturing the state of the analog signal at

these particular moments in time. Digital audio is a collection of such samples, while the information between the samples has been discarded. For digital data to be converted back to an audio signal, these samples need to be reconstructed as the original sine wave. However, as the digital conversion has only saved samples of the original sine wave and not the entire sine wave, this can never really be reconstructed. What is reconstructed is a rough approximation of the original signal. The difference between the original signal and the sampled and reconstructed signal is always audible, even when using some of the world's best converters to do the job.

When we talk about analog sound, we mean, that at no point in the recording or reproduction process has the signal been sampled and reconstructed.

Analog electronics

Analog electronics in audio equipment can be found in all kinds of equipment, even digital. Since the original capturing of sound waves and eventual reproduction through loudspeakers are both analog processes, even digital audio equipment have their analog side. This does not make a digital piece of equipment become analog. There is a common misconception, that if the mixing console is analog and the recording is done on a digital audio workstation, it might be somehow closer to analog. The truth is, that once the signal is sampled, and has been converted to digital, it has forever left the analog domain and can never be precisely reconstructed again. Analog electronics can consist of vacuum tubes, transistors, resistors, capacitors, diodes and many other electronic components, but, so can digital devices. It can be, that you wouldn't necessarily be able to tell if a device is digital or analog just by looking at the electronic components on the circuit. You need to understand how they deal with the audio signals.

Any device, in which the audio signal can be represented in its entirety, is called analog, and any device, in which the audio signal is sampled and/or reconstructed is called digital. There is good sounding and bad sounding examples of both and there are definitely uses for both.

Advantages and disadvantages of digital and analog

The main benefits of digital audio are the lower cost and the possibility to perform much more complicated processing operations, which can not really be done in the analog domain. However, these complicated digital signal processing operations are only really useful to cover up the inadequacies of modern pop stars, while they might be of use in research laboratories for producing results of little to no musical value.

The biggest drawback of digital audio is the sampling. This process essentially throws out parts of musical information, which could otherwise still exist in the signal. The amount of information, which is thrown away and the amount of information, which is retained, is defined by the sampling rate and quantisation of the conversion process. Although we often use sine waves as a theoretical example to make it easier to understand how signals work, in reality, audio signals are complicated waveforms with an incredible amount of information in the form of sonic detail hidden within them. While the main idea, of what used to be the original sound, can usually be retained, a lot of the important details are being thrown out, or even worse, contributing to

unpleasant distortions in the reconstructed audio. The sampling and quantisation errors are greatly exaggerated at lower sampling rates and resolutions.

One of the most commonly used digital formats, the Audio CD, uses a PCM process at 44.1 kHz sampling rate and 16 bit quantisation. This leads to a shocking audible difference in a direct comparison of the original analog signal and a reconstructed version from the CD. The frequency range of the CD is theoretically limited to 22050 Hz, which is the Nyquist frequency of the Sampling Theorem. In this example, the Nyquist frequency defines the highest frequency, that can theoretically be handled in a digital conversion, which is half the sampling rate frequency. Beyond that frequency, aliasing occurs, which audibly destroys the signal. To prevent aliasing, analog filters are used to limit the frequency spectrum which is allowed to reach the converter. Using the CD as an example, if a filter was o be designed with a corner frequency of 20 kHz, which would effectively prevent any signal above 22 kHz in frequency from reaching the converter, it would need to be made remarkably steep, introducing severe phase issues and ringing.

Theoretically, the human ear can not hear sounds over 20 kHz in frequency. However, the vast majority of live music contains a lot of information beyond this point. High definition digital conversions can retain information much higher up in the frequency domain, while in the analog domain this range is even greater.

Although the human ear is pretty much limited to 20 kHz at best, most humans can perceive the presence of higher frequencies in auditory experiences, and their removal alters the experience in some way.

The main disadvantages of analog audio are the limitations in ridiculously complicated processing operations, the cost and complexity of professional equipment and the much higher level of skill required by the operator of such equipment. The advantages are the ability to retain a much greater amount of sonic detail, the ability to perform natural sounding signal processing and the ability of analog storage media to last for centuries.

Phonograph records made over a hundred years ago can still be enjoyed nowadays and magnetic tape recordings, although a bit more demanding in their storage conditions, have been enjoying a similar lifespan. Nobody knows yet exactly how long such media will last, as a lot of them are still surviving. On the other hand, optical media, such as the Audio CD, have a lifespan of around 10 years and solid state media, such as USB drives and SD cards, can only store information for a few months at best, if they are not used regularly. Hard drives are extremely complicated mechanical devices, which also tend to fail at regular intervals. This is precisely, why important digital data is permanently stored on magnetic tape. A major disadvantage of analog media is their size and weight. It is definitely practical to have thousands of hours of audio stored in small portable devices in low quality compressed audio formats. But at the same time, there will always be the people, who will want to enjoy the vinyl record version on their audiophile system.

Once you have the audio captured in a high quality, long lasting format, you can still downgrade it to all the digital convenience formats you like, while still retaining the high quality master, which will outlast all the other formats, which can be created again from the original master.

Apart from the higher quality and ability to defy time, there is another major benefit of ana-

log audio: This is the unique properties of audio electronics and magnetic tape, when operated outside their design limits. Overloaded analog audio electronics and tape saturation have defined the sound of recorded music since its inception. These properties, often described as "warmth", "fatness", "creaminess" and "attitude" are such an integral part of how we are used to perceiving music and are so often used creatively, that they have become the main focus of digital signal processing. Software developers, working on digital audio workstations and signal processing, are desperately trying to emulate analog sound. However, an emulation can never sound as good as the real thing, which is why analog audio is coming back with a vengeance, decades after it was supposedly made redundant.

The effects of information storage

It is important to point out that it is technically impossible to store information on any kind of medium, be it analog or digital, and retrieve it again, without degradation. Analog storage requires energy conversions from electrical to mechanical or magnetic energy back to electrical, while digital storage requires a sampling conversion of an analog electrical signal to a digital electrical signal, a conversion of the digital electrical signal to a magnetic equivalent in the case of the hard drive as the storage medium, back to digital electrical and reconstructed back into a different analog signal.

While all such conversions degrade the signal, analog distortions can be used as a creative tool since they are generally accepted as pleasant sounding, while digital distortion need somehow be masked as they are highly unpleasant. Analog distortions tend to follow the melodic and harmonic structure of the audio due to their nature, while digital distortions are unrelated to the actual signal and as such stand out as spurious interference.

Analog storage media

Although analog audio was the only option for the best part of the existence of recorded sound, there are relatively few analog storage media and formats.

Analog recording can be split into two main categories, magnetic and mechanical recording. Mechanical recording was invented first and refers to media on which laterally and/or vertically modulated grooves are mechanically carved. This started with Edison's phonograph in 1877 and developed into the now commonly used vinyl record. Magnetic recording on the other hand started with the wire recorder in 1888 and evolved into the industry standard for studio recording, reel-to-reel analog tape, in various sizes, as well as the very popular consumer format of the cassette tape, which is also currently experiencing a revival. In magnetic recording, the audio signal is converted into magnetic energy and stored on a magnetic medium, with excellent fidelity.

The principles behind magnetic and mechanical recording are quite different, but they both share the ability to store and reproduce the entire analog audio signal.

Mechanical storage media

Mechanical storage media are wax cylinders, shellac records, vinyl records, acetate records and copper DMM disks. Phonograph records have also been made out of postcards, pic-nic

plates and medical x-ray film, even beer cans, that can be reproduced on a phonograph. Generally, a mechanical analog storage medium can be any kind of object onto which grooves can be carved, which can be reproduced by some kind of stylus following the shape of the groove, converting it into an electrical signal or directly into air pressure variations.

Magnetic storage media

Magnetic storage media consist of reels of wire or magnetic tape, which can either come in open reels or in some kind of an enclosure. Open reels are used in reel-to-reel tape recorders, while the different enclosures can make cassette tapes, elcassettes, 8-track cartridges, microcassettes, VHS tapes on so on.

What is not analog?

As mentioned previously, any instance of a sampled signal is not analog. When it comes to audio, anything not analog is digital. There is nothing in between, no shades of grey, just black and white. It is either analog or it is digital.

It does not matter, whether you just record on your smart phone or if you are using some of the world's most expensive vacuum tube microphone preamplifiers, as soon as you introduce a digital conversion in your signal path, the recording is no longer analog.

Due to analog sound being in fashion at the moment, a lot of recording studios, who either gave up on analog long ago, or never got into analog to begin with, are now trying to attract customers by misleading them into thinking, that they are able to do analog recordings... ON THEIR COMPUTER!

You would not believe some of the things we have heard lately. From people claiming to do analog recording on computers using special "analog software", to people claiming that the CD is an analog format, if it is reproduced on a standalone CD player and not on a computer. Others pretend to do analog recording by buying a beat up multitrack tape machine and routing the outputs of the mixing console to the tape machine and digital audio workstation simultaneously, pretending, that they are recording onto tape while in reality, doing all the work in the digital audio workstation. Some studios even do actually record on multitrack tape, but do not have any analog signal processing units or a stereo tape machine for the mixdown, so they just record from the multi track tape onto the digital audio workstation and do all the mixing and processing digitally, while having the band think, that they are doing an analog recording. We have even heard a story of a band, that got suspicious, when they saw the waveforms appear on a computer monitor, when they thought they were recording on tape. The recording engineer just asked them to leave the room, while he does the mixing!

So, to dispel the myth once and for all, CDs are not analog, computers are not analog, digital effects processors (i.e. rack-mounted reverb units with a little LCD display) are not analog, hard disk recorders and SD card or USB recorders are not analog, software is not analog.

Apart from recording and mastering studios, the scam extends to media production plants. Digital bin loop systems for cassette tape production are not analog and digital delay systems, often used in lacquer/DMM cutting for the production of vinyl records are also not analog. In general, if it is not stored on tape or disk, it is not analog. Remember, there are only two kinds

of analog media, magnetic and mechanical. The only surviving magnetic formats are reel-to-reel tape and cassette tape, while the only way to do analog recording on a mechanical format is, if you do a direct-to-disk recording. For the record, DAT, ADAT, DTRS and other digital magnetic tape formats are also not analog.

But, why would they lie to us?

Well, quite honestly, because it is a major pain in the ass to find, repair, restore and maintain real analog equipment. There are no manufacturers of studio tape machines any more, as there are no manufacturers of professional record cutting lathes, as there are also no manufacturers of cassette duplication systems or even cassette tape. High quality analog mixing consoles and signal processing units are getting rare and expensive. There are very few people left in this world, who know anything about repairing and maintaining such equipment. Most of the equipment used nowadays in a fully analog professional audio facility have probably been manufactured in the 70's and for the past few decades there has been no official support or source for parts. Doing anything with such machines is difficult and expensive. It requires extraordinary skills and dedication to operate such equipment and keep them running. It is understandable, that the vast majority of the so called "engineers" nowadays prefer to use the much simpler and cheaper digital tools to do their job. After all, everyone happens to have a computer at home nowadays and it is easy to download or even buy some software and call yourself an engineer. The audio engineers of the past were most often highly educated, having spent years hunched over a desk studying electronics and mechanical engineering, before moving on to make coffee and clean toilets at radio broadcasting and recording studios, before being allowed anywhere near a mixing console. It would still take years as an assistant near the mixing console before any of them would dare call themselves an engineer.

There are no opportunities for young people to receive a proper education as audio engineers specialising in analog audio nowadays. Educational establishments nowadays only offer courses related to digital audio and the professionals, who do have the knowledge and experience of analog audio, are in danger of extinction. The majority of them are quite old and not all of them are willing to share their secrets.

However, there are still several people left in this world, who do go through all the effort and who do have the necessary skills to keep analog audio alive.

There are several fully analog recording studios, a few fully analog mastering studios, even fewer disk cutting engineers, who work entirely in the analog domain and very few cassette duplication facilities, who are able to work entirely in the analog domain and do a very good job of it, too. Their prices are usually very similar or even cheaper than those of their digital colleagues. There is no reason to compromise, as you can still get what you really want.

Advice

It is good to prepare yourself, before booking a recording, mastering or media production session. Inform yourself about the process and look out for scams.

To give some pointers, if you walk into a recording studio with absolutely no tape machines, not even cassette decks, who tell you,

they can do analog recordings, you had better run away fast. If you see a recording studio with a multi track tape machine but no stereo tape machine or cassette deck, you should still run away fast. A mastering studio with no tape machines or with only one tape machine is another sure sign, that you will not be getting your work done in the analog domain.

Analog mastering can only be done from tape to tape or from tape to disk (lacquer disk, absolutely no CD). If you are delivering a stereo mixdown tape to a mastering studio for pre-masering and want it cut to disk in a separate cutting studio, the mastering engineer needs to be able to deliver an analog master tape. This can only be done, if they have two stereo tape machines, one for reproduction of the stereo mixdown tape and one for recording the master tape.

For cassette duplication, the facility needs to be able to accept an analog master, either as reel-to-reel tape or as a cassette tape. They either need to be using an analog bin loop system, which works with a loop of analog tape, or a bunch of high quality cassette decks. The kind of cassette duplicator, which copies one cassette to three other cassettes is also fully analog, but the sound quality leaves something to be desired.

For producing vinyl records, the cutting engineer must have a reproduce-only tape machine with a preview head and a normal playback head, which would feed a preview signal to the pitch control system of the cutting lathe, before the actual audio signal arrives at the cutter head. It can be possible to cut short duration material, using a tape machine with no preview head or even a cassette deck, but you have to make sure, that the engineer is willing to do the job entirely in the analog domain. A digital delay system or a digital audio workstation are not capable of producing analog cuts. The galvanics and pressing do not affect the analog signal, so you should mostly focus on what the cutting engineer does.

Unfortunately there are professionals out there, who will not hesitate to lie to you about how they work. If you are unsure, ask questions and look around. There are people, who do a good job and will happily work in the analog domain. If analog sound is what you want, do not waste your money with the wrong people. Anything worth doing, is worth doing right.