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Analog and Digital

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What does it mean to be 'digital'? Why has the word 'analog' become synonymous with natural, old, or human? Why exactly is the future digital? Is there a difference between 'data' and 'media'? This report reviews the recent history of analog and digital technology and tries to explain why we went in this direction.

What is 'analog'?

When we speak of analog, we are talking about a type of electronic technology- or a type of information stream. An acoustic guitar for example is not analog, it's physical. Strictly speaking, it is technology based around adding signals to carrier waves, electric guitars and television broadcasts, for example. As we define it further, we'll use sound recording as our example as much of the development of analog electronic technology was done in the media industries.

Thomas Edison and others invented the record player by noticing that sound is small changes in air pressure, which cause things like ear drums to vibrate. Edison made a funnel which channeled sound to a small drum skin (a diaphragm) with a needle attached to it.

When one spoke into the funnel, vibrating the air in a series of high and low air pressure waves, this moved the diaphragm in and out, moving the needle up and down, leaving a scratch of varying depths into a tin foil cylinder that was being moved past it. When the tin foil cylinder was moved past it again, the grooves moved the needle up and down, which vibrated the diaphragm, which vibrated the air, making sound.

Analog electronic equipment works similarly. When we make a sound, we vibrate the air (cause it to have minute high and low pressure areas) which pushes the diaphragm in a microphone in and out. The diaphragm inside it moves a small magnet near which affects an electric current running through a wire.

This electric current goes through the head of a cassette tape recorder (remember those?) and reorganizes the metal filings on a cassette tape, recording the sound. During playback, the metal filings on the tape are moved past the head, which causes the electric current to vary. This current then goes into the speaker, moving another magnet connected to a diaphragm, vibrating the air and making sound. This information is not quantized.

The electromagnetic waves were said to be 'analogous' of the sound waves.

Digital

Computers store information in circuits that resemble billions of tiny switches. The switches are 'binary', having two positions: on or off ('1' or '0' in notation –the oft mentioned 'ones and zeroes'). The definiteness of these states is a solid foundation to build on: you can depend that a value you set will not change. It is very resistant to external noise. In a computer, 0 is represented by a voltage level of 0-0.5 volts. And a one is represented by a voltage level of 4.5-5.0 volts. Those are the only possible values that can be stored. In analog systems, it is difficult to get such a clear measurement, for example, to compare two signals and see if they were the same.

Digital Data from Analog Sources

The goal of having information digitally is to make it understand able by computers. It is not just the language of computers that makes digital attractive, it is also a means of greatly improved archival and storage and duplication. The additional information that can be added to a digital dataset, using typical checksum, CRC, and compression technologies, without altering the information content, make information management much more robust. The key in having useful digital data is to get a sampling rate that gives a sufficiently accurate representation of the phenomenon being investigated. A sufficient resolution has to be chosen so that all parties agree that the digital version is the same as the original. For music that level is has been defined, for fine art and many other fields, it hasn't.

Analog music existed alongside digital computers for some 30 years, until computers were sufficiently fast to handle the huge volume of data in analog media. Analog information is a recording of a continuous stream of changes, usually expressed in waves, which computers don't know how to deal with. To use it, the stream gets measured at regular intervals and recorded as a series of numbers. The 'sampling rate' mentioned on CD players is the number of times a second it measures the voltage level. This number can be stored and manipulated like all the other numbers computers deal with.

Unfortunately, all the detail that happens between those two intervals is discarded. This is visible in the figure below near where the wave crosses the horizontal line in the center drawing. When the sound is output, the numbers are interpolated to recreate the original wave as best as possible. If this rate is fast enough, we do not notice this loss of detail. For vision, this rate is 24 samples (frames) per second. CDs are 44,100 samples per second. MP-3 (using some of the more popular high compression, small file size sampling rates) give noticeably less. Audiophiles think standard CD rates are not sufficient and MP-3 even worse. Ever listen to an MP-3 through a good stereo? Not that impressive a reproduction. Sony sells a 'super-cd' that has significantly higher bit rates and bit depths.

Why Go Digital?

Analog technology is very effective and is still used extensively. Some of the aspects of analog technology are quite beautiful. The entire process is deals with continuous physical properties-air vibrations moving magnets to fluctuate current. Not just that, there are also analog computers, a lot of which are feedback devices. A motor can have an encoder on it that represents motor speed as a varying voltage. By constructing analog proportional, integrating, and derivative circuitry, you can construct a real time analog computer that does not have a clock frequency or a rated processor speed but gives a continuous correcting signal to the motor controller. The recording and playing process are symmetrical, it gets recreated in the way it was recorded. That said, our technological culture has moved toward digital technology. The reasons for digitizing the information are complex and somewhat surprising.

Cheap Accuracy

Cost is an extremely important factor in the success of a technology. Digital systems provide good accuracy at a low cost. Records contain much higher sound resolution than CD's, but require the precision of high-end record players, costing thousands of dollars to get at it. A $100 CD player will give you excellent sound reproduction. This follows the general shift toward chip based logic replacing mechanisms, reducing wear. The record needle eventually wears out its groove, the magnetic cassette tape head eventually erases the tape.

Analysis, Manipulation, & Communication

Computers are essentially designed to compute, to do math and compare values. To 'digit-ize' is to convert complicated information into numbers. Once digitized, information can be more easily stored, manipulated and analyzed. Analog information is modified and duplicated, but without detailed analysis.

The undefined character of the computer allows software tools to be created to accomplish multiple functions. Once information has been measured, it can use the infrastructure, from floppy disks to the internet, to be modified and sent to others.

Error detection is an interesting benefit of digital transmission, and a necessary element of working with data. A record player cannot tell a scratch in a record from a recording, but missing a small piece of a program would be catastrophic. With every chunk of information, a corroborating number is added, for example, a simple sum of the previous values. The reader/receiver compares the data and the corroborating number; if they don't match, there is a problem.

When data is described as a series of numbers, it can be compressed into less space. A common form of compression simply replaces repeating information with a description, such as '5 seconds of silence'.

Is Digital 'Better' Than Analog?

In engineering terms, one can never describe something as better, with out describing what one is measuring. On one level, we are witnessing a cultural shift from 'media' to 'data'; toward more analyzed and optimized communication. The speed with which the music recording industry switched to digital editing testified to its convenience in the production of it. The massive trading of MP3s shows that digital technology can be a powerful tool for the user.

Further reading

http://www.howstuffworks.com/analog-digital.htm

http://www.howstuffworks.com/question7.htm