Digital hi-fi and TV

Computer-like circuits enhance audio and video

New equipment promises super-fidelity in sight and sound

By JOHN FREE

The digital electronics revolution that brought you the pocket calculator, digital wristwatch, TV games, and home computers is beginning to influence the way audio high-fidelity signals are recorded, stored, and played back, plus the television pictures you watch.

Nothing new, you say? We've been saturated with ads for computerized and digitized TV's, FM tuners [PS Nov. '77], turntables, tape decks, and other products for years. The digital circuits for these products are designed to simplify tuning, give you digital readouts of speed, channel, or frequency, and provide smoother, more accurate mechanical performance. In each case, the circuitry helps control the continuous analog signals used for audio and video.

But now engineers have developed techniques to digitize the analog audio and video signals themselves. And the improvement in high-fidelity sound is so dramatic that few hi-fi systems or listening rooms are good enough to take full advantage of digitized audio.

Some of the new devices that bring about this radical improvement will be described shortly. But first, what makes a digitized

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Audio-disc player from Sony (below) provides ultrahigh-fidelity sound as a laser beam reads digitally coded signals on reflective discs. Production players will be smaller than prototype.

Dual-function players and discs under development by Hitachi (above) can play either audio or video discs. Machine is first to use a tiny semiconductor laser, which simplifies construction.

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signal so much better than the continuous analog electronic signals from discs, tape, and other sources?

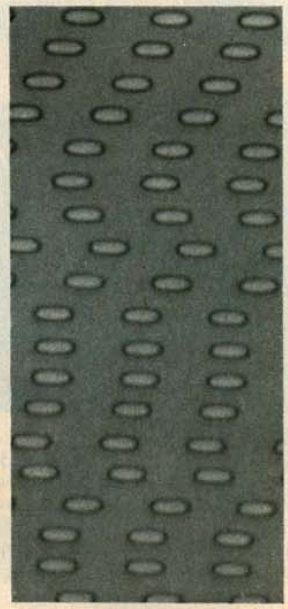
One factor is that analog signals constantly change in amplitude and frequency. Weak, low-level analog signals can be drowned out or distorted by noisy storage mediums (tape hiss) or during transmission (snowy TV pictures). Both low- and high-level signals may have their amplitudes and frequency characteristics distorted by amplifiers.

Coded signals

Digital signals, however, are simply a series of on-or-off, constant-amplitude pulses. The order of these pulses can be arranged (coded) to represent any analog signal converted into a digital format. But most important, the circuits used to convert digitized signals back into analog form will only recognize properly coded pulses. Noise, such as tape hiss, is ignored and you don't hear it.

Moreover, digital signals are far less susceptible to distortion during transmission. And even if the signal is distorted, if the digital decoder can recognize the on-off pulse sequences, it can still recreate an analog signal that's audibly or visually identical to the original.

Recording/playback adapter (left) for Sony's or other video-cassette recorders puts digitized audio signals on the cassette-tape tracks that normally store video signals. Fidelity exceeds that of nondigital professional recorders.



Optical disc-player system made by Mitsubishi and others has a dynamic range exceeding 98 dB. Spiral tracks of pits on discs (magnified at right) are about 0.6 microns wide, have a protective plastic coating against dust and smears.

The idea behind this important advance isn't new. In fact, the principle behind the digital technique often used, called pulse-code modulation (PCM), was patented by British engineer Alec Reeves in 1939. Engineers have applied digital concepts for years to military, space, and commercial communications. But only now, with low-cost microcircuits readily available [PS, Jan.], have the same concepts become feasible for home-entertainment products.

The new techniques banish ticks and pops from discs, totally eliminate background hiss from tapes and discs, reduce wow and flutter to unmeasurably low levels, and boost the dynamic range of music—the difference between soft and loud sounds—to levels approaching that of a concert hall.

Changes in the pictures on your TV screen with digital technology are more subtle, but the new methods are already making significant changes in broadcast television.

Digital hardware

Last year, an eye-opening variety of new devices—most of them several years from market introduction—were unveiled at audio shows here and in Japan.

The new digital hardware, and the ways digital techniques can be applied to TV broadcasting, fit into several categories:

- Audio discs and players using digitally coded signals are under development by several Japanese firms. These machines work much like the Philips-MCA video discs [PS, Feb. '77] now scheduled for introduction this year.
- Tape recorders and video-cassette-recorder (VCR) adapters with digital signal encoding are also abundant in prototype form. One VCR adapter (Sony's) is already being sold. The adapters work with any of the VCR's on the market [PS, Nov. '77] and enable owners to use their decks for recording either ultrahigh-fidelity audio or TV programs.
- Hi-fi power amplifiers using a special type of digital circuit can be made much smaller than conventional amps. These so-called Class-D or switching amplifiers use power superefficiently instead of wasting energy in the form of heat.
- Digital video circuits are already being used by broadcasters

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in the long chain of amplifiers and switches that process signals between camera and transmitter.

● Digital TV signals broadcast to your home like a conventional VHF or UHF signal are unlikely for reasons explained later. But some day home TV receivers may pick up digital TV pictures beamed to special roof-top antennas from satellites [see "Satellite-to-you TV," page 66]. Other homes may receive extremely high-quality digital TV pictures through coaxial cable or hair-thin glass fibers [PS, August '75].

Analog limitations

The availability of low-cost circuits is one reason engineers are looking at digital technology for home entertainment. But audio experts also want to minimize or eliminate the many technical problems that plague conventional tape and disc recordings.

Most recordings start on professional analog-type tape machines, which, despite their quality and high prices, immediately limit the dynamic range of a recording. Loud high-frequency signals can easily saturate the magnetic particles on tape, causing distortion. At the other extreme, faint music signals often must be boosted in amplitude so they aren't buried in the high-frequency background hiss.

Because of these tape limitations, recording engineers and home recordists as well must restrict the dynamic range of recordings, losing much of the sonic impact and excitement of the live performance. Musical peaks are electronically and manually limited (a knob).

The problems are compounded when taped signals are transferred to plastic discs and mass produced. Fragile disc surfaces scratch easily, while dust and dirt attracted to the grooves are ground in by the stylus to cause permanent damage. Further, the restricted dynamic range from the tape may have to be compressed more. Record companies must insure that during loud passages the groove-cutting stylus doesn't create grooves that cause distortion or throw your stylus out of contact.

Most audio discs, therefore, convey a feeble imitation of the 100 dB or so difference between an orchestra's loudest and lowest-level passages. Good discs produced from

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Digital encoding of the conventional analog signals for TV pictures requires enough pulses in the digital words representing amplitude levels to recreate the image. A three-bit-long digital word, left, clearly reduces detail in flat areas. An eight-bit word, right, provides an excellent TV picture.

a master tape may achieve a 65-dB dynamic range. (For reference, each six-dB increase in sound is perceived as being twice as loud.)

The British Broadcasting Corp., obliged to provide quality stereo FM throughout Great Britain, was among the first to apply digital-signal encoding to home entertainment.

Digitized FM

During the late 1960's and early 1970's, the BBC devised a method of transmitting digitized stereo FM over the telephone lines and microwave links connecting studios and transmitters throughout Great Britain.

An analog output signal from, say, a BBC master tape is sampled thousands of times each second. Each sample, which represents the amplitude of the analog waveform at an instant in time, is coded into a series of on-off pulses called a digital code word (see box, p. 60). As the tape plays, a stream of digital words representing the music can be sent over phone lines or microwave hundreds of miles to various BBC studios.

What happens if the digitized signal is distorted along the transmission path? Signal distortions that might garble an FM analog signal have virtually no effect on a digital signal. The digital-to-analog (D/A) converter at each BBC studio need only recognize how the on-off pulses in each word are organized to recreate the exact analog signal amplitude. Digital words must almost be knocked out of the data stream before the D/A converter fails to do its job. Moreover, duplicate code words can be sent so that losing some words may have no effect at all.

After the BBC upgraded the reliability and quality of its FM transmission links, it next wanted a practical tape machine to record and play signals in a digitized form. In 1975, the BBC and 3M Company began a joint development project on a commercial digital recorder. Late last year I saw 3M's new $150,000 digital recorder at a press conference.

A demonstration tape on the professional machine had an awesome clarity and dynamic range. But the demonstration room—as with most home environments—was too noisy for us to fully appreciate the recorder's 90-dB dynamic range. The machine can record 32 separate tracks—each for separate performers, if desired—on special one-inch-wide tape.

With the techniques the BBC and 3M devised to encode audio signals, specifications such as wow and flutter, distortion, crosstalk (interference between tracks), and print-through have become inaudible or exceptionally low.

But the exciting news in the audio field is the large number of digital tape and disc machines being developed in Japan for home use. With these new machines, the superb fidelity captured by 3M's professional recorder can be transferred to mass-produced discs and tapes with absolutely no loss in sonic quality.

Most of the new digital machines are in the prototype stage and may not be available for a few years. At least nine Japanese firms have unveiled digital audio gear.

In some respects, a few of the products designed for home use are superior to 3M's costly professional tape machine. Sony's PCM disc player, for example, has a flat frequency response (not deviating more than 0.3 dB) from two Hz up to 20 kHz; 3M's tentative response specifications for the same tolerance extend from 30 Hz to 15 kHz. (The 3M machine actually covers 20 Hz to 20 kHz without significant deviation.)

Dual-mode player

The prototype disc systems from Sony, Hitachi-Nippon Columbia, and Mitsubishi-Teac-Tokyo Denka use an optical recording and playback system. Discs must be recorded at the factory. Hitachi and the firms cooperating with it are working on a two-mode disc player that can produce either video images or ultra-high-fidelity sound.

With these audio disc systems, the PCM-encoded audio becomes a spiral track of pits or bumps on the disc surface. The Philips-MCA video discs have similar tracks, but the signals are not PCM-encoded before conversion into a spiral track. As the audio disc spins at 1800 rpm, a laser beam reflected from the track is decoded into the stereo signal. To prevent problems from dropouts, about 50 percent of the digital PCM pulses are redundant. The D/A decoding circuits can sense when a dropout has occurred and use a duplicate signal.

Although PCM audio-disc players aren't available yet, in Japan Sony is selling its adapter for video-cassette recorders. This device converts a VCR into an ultra-high-fidelity audio tape recorder. The adapter (see photo) costs about twice as much as a VCR deck.

Matsushita and Mitsubishi have also shown VCR adapters. Like Sony's, these plug-in devices convert conventional analog audio signals into a PCM signal format, then into a video-type signal that the VCR can process. The encoding process is reversed during playback and the output of the adapter is plugged into a hi-fi system like any other tape machine.

Sony is also refining a different kind of digital technology that involves amplifying audio signals to drive loudspeakers. It plans to market a so-called Class-D or pulse-width-modulation (PWM) hi-fi power amplifier. An early prototype model I saw delivered 150 watts per channel, but weighed only 22 pounds and was surprising-

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