Video and the Origins of Electronic Photography

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Published in translation as "La vidéo et les origines de la photographie électronique," *Transbordeur: Photographie histoire société* 3 (2019): 26–35.

Over the last two decades, electronic media have usurped their photochemical predecessors. Most of what we now call photography is produced by light striking a charge-coupled device rather than silver halide crystals. Electronic imaging technology has largely replaced both still and moving image film.

We've come to associate this technological revolution with digital media, programmable machines capable of reducing many forms of information—including the light captured by electronic sensors—into a single binary representation. "The general digitization of channels and information," argues Friedrich Kittler, "erases the differences among individual media.… Inside the computers themselves everything becomes a number: quantity without image, sound, or voice.… A total media link on a digital base will erase the very concept of medium."[1]

Digitization was not, though, the moment at which photography began to share a medium with sound and quantification. Our current association of the digital with progress can distract us from the historical fact that the most sophisticated electronic technologies have often been analog ones, processing information as continuous variations in voltage or current and recording it as continuous variations in magnetic fields. The discourse of the digital can also obscure continuities between electronic media, preventing us from seeing how much analog and digital modes of representing information have in common.

Rather than thinking of the recent decline of film as a process of digitization, we might just as productively see it as a culmination of the rise of electronic photography, a phenomenon that has introduced into our visual experience not only the digital but also the analog. As we replace chemical and mechanical media with digital simulations of them, we have made the dichotomy of analog and digital a totalizing one; it is now common to use the word analog to refer to any medium which is not digital. Historically, though, *analog* referred to two specific features of a technology: an analog technology was one which represented one physical phenomenon, such as luminance, sound volume, or velocity, by another, usually voltage or current (but in some cases water pressure or other non-electrical forces), and in which both phenomena varied continuously rather than discretely.[2] Making the photographic image electronic—representing it with

1 Friedrich A. Kittler, *Gramophone, Film, Typewriter*, trans. Geoffrey Winthrop-Young and Michael Wutz (Stanford: Stanford University Press, 1999), 1–2.

2 In the history of technology, the historiography of the analog has focused on analog computing, particularly in military contexts. This literature includes Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, Mass.: MIT Press, 1996); James S. Small, *The Analogue Alternative: The Electronic Analogue Computer in Britain and the USA, 1930–1975* (London: Routledge, 2001); David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics* (Baltimore: Johns Hopkins University Press, 2002); Paul E. Ceruzzi, *Computing: A Concise History* (Cambridge, Mass.: MIT Press, 2012); and Ronald R. Kline, *The Cybernetics Moment; or, Why We Call Our Age the Information Age* (Johns Hopkins University Press, 2015).

variations in the flow of electricity—brought it into a common medium with other kinds of information well before it became digital.

Placing digital photography in a longer history of electronic photography also situates it in a military history, as efforts to transmit and record the electronic image have often been motivated and funded by their applications to war. American engineers improved video cameras during World War II in order to install them in drones—a word first applied to remotely controlled aircraft in the 1930s—and glide bombs.[3] Meanwhile, German engineers improved audiotape recorders which after the war Americans appropriated and developed into not only videotape recorders, but also data recorders for missile tests and other new forms of armed technoscience. To trace the history of the electronic image is also to excavate its military origins.

Michael Shamberg and Raindance Corporation, *Guerrilla Television* (New York: Holt, Rinehart and Winston, 1971), part 2, p. 31.

Analog Images

For much of its history, electronic photography has taken the forms of television and video—terms that were themselves once synonymous, and became distinct only in the late 1950s when *video* began to refer instead to the new technology of videotape.[4] While chemical photography is intrinsically made up of still images, video was intrinsically a medium of motion. A film camera exposes an entire frame of film to light at once, impressing an image upon it uniformly for

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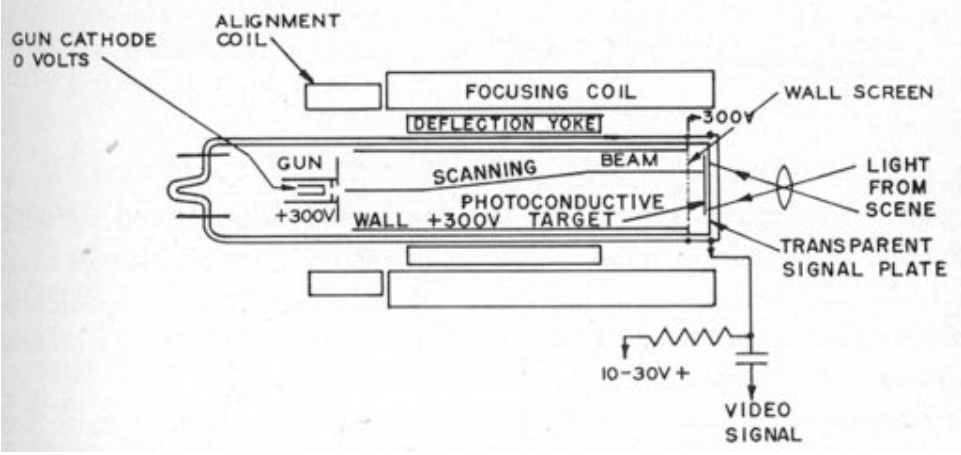
The fact that the two defining features of the analog don't always come together—that a technology can employ continuity without analogy or, as when we model physical phenomena in modern digital computers, analogy without continuity—has frustrated users of the words *analog* and *digital* almost since they took on these technical meanings. "These names confuse people. They are bad names," said psychologist J. C. R. Licklider, later a crucial science administrator in the development of the internet, in 1950. Kline, *Cybernetics Moment*, 49.

3 Steve Zaloga, letter to the editor, *Defense News*, May 13, 2013, 20.

4 Michael Z. Newman, *Video Revolutions: On the History of a Medium* (New York: Columbia University Press, 2014), 2, 7–19.

however long its shutter is open. When we rapidly sequence film with a projector to produce the illusion of motion, again every portion of a given frame is exposed to light—and thus projected onto a screen—simultaneously, so that to view a film is truly to view a series of discrete still images. In most ways, film was (and is) neither analog nor digital: it represents light with light itself, making no analogy between physical phenomena; breaks time into discrete moments; and embodies continuity only in that light varies continuously (at least down to the discrete level of film grain) across a frame.



P. K. Weimer, S. V. Forgue, and R. R. Goodrich, "The Vidicon: Photoconductive Camera Tube," *RCA Review* 12, no. 3 (September 1951): 309.

Television and video are different. In the Image Orthicon, a camera tube which the Radio Corporation of American developed to improve reconnaissance during World War II—and which dominated television production during the two decades that followed—a layer of photoemissive cesium-silver oxide coated the front of a piece of Corning semiconducting glass. Photons striking this surface released electrons through the glass. An electron beam scanning across the back of the glass in a raster pattern discharged the positively charged areas, returning a stronger current to the back of the tube when less light was hitting its front. This flow of electricity was then amplified to produce an inverted video signal.[5] RCA and the US Army Air Force installed such cameras into unmanned planes which were remotely flown by pilots in other planes—drones—as well as into guide bombs and guided missiles.[6]

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5 Paul K. Weimer, interview by Mark Heyer and Al Pinsky, July 8, 1975, IEEE Global History Network, last modified April 8, 2015, http://ieeeghn.org/wiki/index.php/Oral-History:Paul_K._Weimer; Kenyon Kilbon, "Pioneering in Electronics: A Short History of the Origins and Growth of RCA Laboratories, Radio Corporation of America, 1919 to 1964" (August 1964), David Sarnoff Library, last modified October 31, 2014, http://davidsarnoff.org/kil.html, 154.

Encyclopedic accounts of the technical history of video and television cameras can be found in the work of Albert Abramson: *Electronic Motion Pictures: A History of the Television Camera* (Berkeley: University of California Press, 1955); *The History of Television, 1880 to 1941* (Jefferson, N.C.: McFarland, 1987); and *The History of Television, 1942 to 2000* (Jefferson, N.C.: McFarland, 2003).

6 RCA Victor Division, Radio Corporation of America, "RCA's Contribution to the War Effort through Television, 1937–1946" (Camden, RCA Victor Division, 1946), Early Television Foundation and Museum, http://earlytelevision.org/military_tv.html, last modified April 7, 2015; Kenyon Kilbon, "Pioneering in Electronics: A Short History of the Origins and Growth of RCA Laboratories, Radio Corporation of America,

Such cameras and monitors were examples of what the engineers designing computers—a domain in which, unlike video, multiple techniques for representing information were competing—were just coming to call analog electronics. They represented one continuous phenomenon, luminance, with another, electric current, and did so by moving an electron beam continuously and smoothly. Even this technology, though, had two elements which were discrete. First, the electron beam scanned in rows, sweeping continuously from left to right and then abruptly dropping down a designated distance to sweep back from right to left. Second, when it had scanned the entire surface, the beam returned to one corner and began again, starting a new frame. A cathode ray tube video monitor followed a similar process in reverse; an incoming video signal varied the current of an electron beam, which scanned across a phosphorescent screen in a raster pattern. The video signal itself was constructed by continuous scanning in the camera, sent continuously over a wire or radio transmission, and represented by continuous scanning on a screen, but it was broken by convention and by timing circuits—usually synchronized by the alternating current of the electric grid, and thus at 60 Hz in the United States and 50 Hz in Europe—into discrete frames analogous to those of film.

Magnetizing Sound

The electronic image was always in motion. While chemical photography fixed an image on film, and transporting that image across space presented technical challenges sometimes solved by making it electronic, as in wire photography, television was at first oriented towards transmission, leaving storage as a complicated technical challenge. In its origins, the electronic image was always live, never recorded. The first solution to this challenge was kinescoping, which involved filming a television monitor. This resulted in an aesthetic different from that of a live broadcast, and film had to be chemically developed, requiring additional work before rebroadcast.[7]

Videotape, the technology that made it possible to record electronic images electronically rather than photochemically, emerged out of an analog technological system distinct from both film and television, that of magnetic recording, which also expanded rapidly in its capabilities during World War II. Magnetic recording was not entirely new, though; Danish telephone technician Valdemar Poulsen had invented the telegraphone, which recorded telephone messages by magnetizing steel wire, in 1898, and German, British, American, and Swedish engineers built recorders that used steel tape in the 1920s and 1930s.[8]

In the 1920s, Austrian inventor Fritz Pfleumer developed a process for adhering powdered bronze to cigarette paper, then built a machine that recorded on a strip of paper coated in particles of iron. In 1932 he formed a partnership with German electrical equipment company

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1919 to 1964" (August 1964), David Sarnoff Library, last modified October 31, 2014, http://davidsarnoff.org/kil.html, p. 155.

7 Frederick Wasser, *Veni, Vidi, Video: The Hollywood Empire and the VCR* (Austin: University of Texas Press, 2001), 57–58.

8 Mark Clark and Henry Nielsen, "Crossed Wires and Missing Connections: Valdemar Poulsen, the American Telegraphone Company, and the Failure to Commercialize Magnetic Recording," *Business History Review* 69, no. 1 (Spring 1995): 1–7, 9; Mark H. Clark, "Steel Tape and Wire Recorders," in *Magnetic Recording: The First 100 Years*, ed. Eric D. Daniel, C. Denis Mee, and Mark H. Clark (New York: IEEE Press, 1999), 33–40.

Allgemeine Elektricitäts-Gesellschaft to make recorders. AEG in turn enlisted chemical company IG Farben, which began developing paper and plastic tapes.[9]

Audiotape became part of German military infrastructure during World War II, a means of centralizing state control of instruments of propaganda, command, and communication. After AEG began manufacturing the Magnetophon in 1935, it was adopted by German radio network Reichs-Rundfunk-Gesellschaft, which had been taken over by the Nazi party in 1933. Magnetophons were installed in radio stations throughout occupied France as well as at Radio Luxembourg's high-power transmitter, facilitating the standardization of broadcasts. "Almost none of the radio station output was live," writes Basil Lane, "since tape was used as a method of censoring the programmes."[10] According to David Morton, German radio stations, "once controlled by the Nazis, also used the magnetophon to broadcast lengthy classical music programs intended to inspire the public," recordings that might have been less effective if dependent on the low fidelity and short duration of contemporary phonograph records.[11]

What made this high-fidelity broadcasting possible was a technical feature added to the Magnetophon in 1941, after it had established its hegemony. Adding a high-frequency alternating current signal to a recording, engineers at RRG discovered accidentally, could compensate for noise introduced by the magnetic medium itself and produce higher fidelity recordings, a phenomenon that became known as AC biasing.[12] Although this discovery had been made independently in the United States and Japan in the 1930s, it was only commercialized in Germany.[13]

At the end of the war, US Army Signal Corpsman John Mullin obtained two high-fidelity, AC biased Magnetophons and shipped them back to the United States as "war souvenirs."[14] Mullin demonstrated these machines at a meeting of the San Francisco chapter of the Institute of Radio Engineers in 1946. One witness to Mullin's demonstration, mechanical engineer Harold Lindsay, would soon be hired by Ampex—a California company making small motors and generators for the US Navy's airborne radar systems—and suggest that they develop their own audiotape recorder based on the Magnetophon.[15]

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9 Friedrich K. Engel, "The Introduction of the Magnetophon," in Daniel, Mee, and Clark, *Magnetic Recording*, 47–50, 65–66.

10 William Charles Lafferty, Jr., "The Early Development of Magnetic Sound Recording in Broadcasting and Motion Pictures, 1928–1950" (PhD diss., Northwestern University, 1981), 137–138; Basil Lane, "75 Years of Magnetic Recording: 3—From Steel to Plastic," *Wireless World*, May 1975, 222.

11 David Morton, *Off the Record: The Technology and Culture of Sound Recording in America* (New Brunswick: Rutgers University Press, 2000), 57–59.

12 Lafferty, "Early Development of Magnetic Sound Recording," 139–141.

13 Mark Henry Clark, "The Magnetic Recording Industry, 1878–1960: An International Study in Business and Technological History" (PhD diss., University of Delaware, 1992), 122–123; Peter Hammar, "The Birth of Tape Recording in the U.S.," paper presented at the 72nd Convention of the Audio Engineering Society, Anaheim, Calif., October 1982, last modified September 17, 2011, http://www.historyofrecording.com/support-files/aes_preprint_1928_1982-09_birth_of_tape_recording.pdf, p. 2.

14 John T. Mullin, "Creating the Craft of Tape Recording," *High Fidelity and Musical America*, April 1976, 63–64; John T. Mullin, "The Birth of the Recording Industry," *Billboard*, November 18, 1972, 58.

15 John Leslie and Ross Snyder, "History of the Early Days of Ampex Corporation" (December 17, 2010), Audio Engineering Society Historical Committee, last modified April 19, 2012, http://www.aes.org/aeshc/docs/company.histories/ampex/leslie_snyder_early-days-of-ampex.pdf, pp. 1–3; Harold Lindsay, "Magnetic

Meanwhile, crooner Bing Crosby was seeking a new, high-fidelity technology for recording sound. From 1935 to 1945 Crosby had broadcast *The Kraft Music Hall* on National Broadcasting Corporation radio. He resented the requirement that he perform live, though, particularly since he had to do so twice to reach both eastern and western audiences. In 1946 Crosby left NBC for the new American Broadcasting Corporation, which permitted him to record on acetate or lacquer "electrical transmission" disks instead, but ratings suffered along with the fidelity of his broadcast voice. In 1947, then, Crosby began recording his new show *Philco Radio Time* on one of Mullin's Magnetophons, which he had set up at NBC's Hollywood studios.[16]

Ampex Model 200-A marketing brochure, c. 1948, from Howard Sanner, "Ampex Literature," Ampex Virtual Museum and Mailing List, last modified July 31, 2010, http://recordist.com/ampex/apxlit.html.

Recognizing the potential of this new medium, Crosby loaned Ampex $50,000 to put their Model 200 recorder into production and became Ampex's distributor, selling machines to ABC. "In April 1948," write Martin McQuade and Peter Hammar, "the first two machines from the Ampex assembly line went to Mullin in Hollywood to record the Philco show. More recorders went to ABC's WLS Chicago affiliate to time-shift the program for the Eastern and Central time zones, while yet more Ampex machines went to New York and Hollywood to fill an instant demand for the incredible new recording technology."[17] Magnetic recording, then, facilitated the

Recording Part I," *dB: The Sound Engineering Magazine*, December 1977, 38–39; Lafferty, "Early Development of Magnetic Sound Recording," 167–168.

16 Martin McQuade and Pete Hammar, "Bing Crosby's Magnetic Tape Revolution," in *Going My Way: Bing Crosby and American Culture*, ed. Ruth Prigozy and Walter Raubicheck (Rochester: University of Rochester Press, 2007), 151–155.

17 McQuade and Hammar, "Bing Crosby's Magnetic Tape Revolution," 155–156.

standardization of broadcasting in the United States as it had in Europe, making it possible for the whole country to hear the same program with the sound quality audiences associated with a live performance. "Critical listeners," boasted Ampex engineers, "have not been able to determine which is the original program and which the reproduction."[18]

Magnetizing Video

"It was not until after AEG and BASF developed a high-frequency and thus an extremely high-fidelity magnetic audiotape during World War II," suggests Friedrich Kittler, "that it was also possible to conceive of an analog optical storage device."[19] Among those who did so was Mullin, who in 1950 began developing a videotape recorder at Bing Crosby Enterprises.[20] In 1951 David Sarnoff, the chairman of RCA who was made a brigadier general for supervising the repair of radio stations in Paris after D-Day, announced that his company was also designing such a recorder, and that it would be commercially available within five years.[21]

It was Ampex, though, that had a videotape recorder—built largely from their audio components—ready for introduction at the 1956 National Association of Radio and Television Broadcasters Convention. Funded in part by the Columbia Broadcasting System, a competitor of Sarnoff's NBC, the Ampex VR-1000 filled the same role in television that audiotape recorders did in radio, allowing broadcasters to capture otherwise ephemeral electrical signals.[22] "It was very clear in the United States," recalled Ampex engineer Martin Salter, "that there was only one seen application of the tape recorder and that was time-delay, to be able to have something at the same local time, on the East Coast, on the Mid and on the West Coast."[23]

As with high-fidelity audio recording, video recording presented a substantial new technical challenge. In this case, it was the challenge of density. Both Mullin and RCA initially recorded signals linearly, using up to thirty feet of tape per second—an entire foot for each frame of the television image.[24] Ampex instead used a technique called "transverse scanning," mounting a drum perpendicular to the tape so rotating heads could record a signal across the width of the tape as it went by. As Glenn Bugos writes, "Ampex surged past companies like RCA by making

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18 Harold Lindsay and Myron Stolaroff, "Magnetic Tape Recorder of Broadcast Quality," Audio Engineering, October 1948, 13.

19 Friedrich Kittler, *Optical Media: Berlin Lectures, 1999*, translated by Anthony Enns (Cambridge: Polity, 2010), 221. There was at least one (non-magnetic) exception: In 1928 Scottish electromechanical television inventor John Logie Baird also invented a system, Phonovision, for recording video onto phonograph records. Abramson, *History of Television, 1880 to 1941*, 128.

20 McQuade and Hammar, "Bing Crosby's Magnetic Tape Revolution," 157.

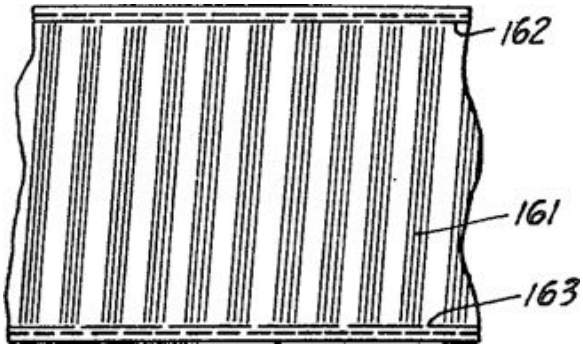
21 Abramson, *History of Television, 1942 to 2000*, 53; Erik Barnouw, *The Golden Web* (New York: Oxford University Press, 1968), 201.

22 Leslie and Snyner, "History of the Early Days of Ampex Corporation," 10–11.

23 Jeff Martin, "The Dawn of Tape: Transmission Device as Preservation Medium," *Moving Image* 5, no. 1 (Spring 2005): 54.

24 James Lardner, *Fast Forward: Hollywood, the Japanese, and the Onslaught of the VCR* (New York: W. W. Norton, 1987), 56; Finn Jorgensen, "Early Fixed-Head Video Recorders," in Daniel, Mee, and Clark, *Magnetic Recording*, 147.

magnetic recording a mechanical problem."[25] By taking advantage of a tape's two inches of width as well as its length, the VR-1000 consumed only fifteen inches of tape per second—or half an inch per frame—fitting ninety minutes of video onto a reel fifteen inches in diameter.[26]



Charles P. Ginsburg, Shelby F. Henderson Jr., Ray M. Dolby, and Charles E. Anderson, Broad band magnetic tape system and method, US patent 2,956,114, filed July 24, 1955, and issued October 11, 1960, sheet 5.

A margin at one edge of the tape was used for a control track, a regular rhythm of pulses marking the beginning of each frame used to regulate playback speed—the digital component of analog videotape. The other margin was reserved for audio, which was recorded linearly using the circuitry from an Ampex Model 350 audiotape recorder.[27] Audio was thus literally marginalized in videotape recording.

Ampex trademarked the word *Videotape* and sold recorders "to all major telecasting networks, and to many network-affiliate and independent TV station in the U.S. and several foreign countries," including Canada, Japan, England, and Germany by 1958 and another 23 by 1961.[28] For nearly a decade, the cost and bulk of video technology made it accessible only to television broadcasters; the VR-1000, for example, weighed 1465 pounds and cost $45,000 in 1956.[29]

For the most part, their use was limited to recording programs so they could be rebroadcast to western audiences, replacing kinescoping. In 1957, though, NBC and CBS "startled their viewers," according to the *Washington Post*, by rebroadcasting Dwight D. Eisenhower's presidential inauguration "within an hour" of its initial, live broadcast.[30] Six years later, CBS introduced instant replay to American sports broadcasting during an Army/Navy college football

25 Glenn E. Bugos, "The Aerospace Impetus to Silicon Valley," *Journal of the West* 36, no. 3 (July 1997): 102.

26 Lardner, *Fast Forward*, 59.

27 Leslie and Snyner, "History of the Early Days of Ampex Corporation," 10.

28 Ampex, 1958 Annual Report, box 16, series 2, Ampex Corporation Records, Special Collections, Stanford University Libraries, pp. 9, 26; Ampex Corporation, 1961 Annual Report, box 16, series 2, Ampex Corporation Records, p. 13.

29 Ampex, VR 1000 Videotape Recorder Instruction Manual (1958), box 15, series 2, Ampex Corporation Records, p. PFD-1; Abramson, *History of Television, 1942 to 2000*, 73.

30 Martin, "Dawn of Tape," 54; Laurence Laurent, "Viewers Startled by Tape's Quick Repeat," *Washington Post and Times Herald*, January 22, 1957.

game. “This is not live!” explained the announcer. “Ladies and gentlemen, Army did not score again.”[31]

Ampex VR-1000 Videotape Recorder in use, Dallas television station KRLD, c. 1960. Andrew K. Dart, “The First Videotape Machines at KRLD-TV,” last modified December 13, 2010, http://akdart.com/vtr/vtr3.html.

Magnetizing Information

In the late 1940s, Mullin became not only Crosby’s recording engineer, but also a salesman for Bing Crosby Enterprises. Working with Raytheon personnel at Naval Air Station Point Mugu near Los Angeles, in 1949 he developed techniques for recording flight data received by radio from experimental planes and missiles.[32] “This data,” explained a 1957 Ampex annual report, “once recorded on the tape, could be played back any number of times in the laboratory and, in essence, the flight was re-created over and over again.”[33] In the 1950s, Ampex controlled the majority of the “instrumentation recorder” market, and aerospace equipment accounted for half its sales. NASA installed Ampex data recorders in space capsules, and the military placed them in reconnaissance aircraft that flew over Vietnam.[34]

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31 Dylan Mulvin, “Game Time: A History of the Managerial Authority of the Instant Replay,” in *The NFL: Critical and Cultural Perspectives*, ed. Thomas P. Oates and Zack Furness (Philadelphia: Temple University Press, 2014), 43.

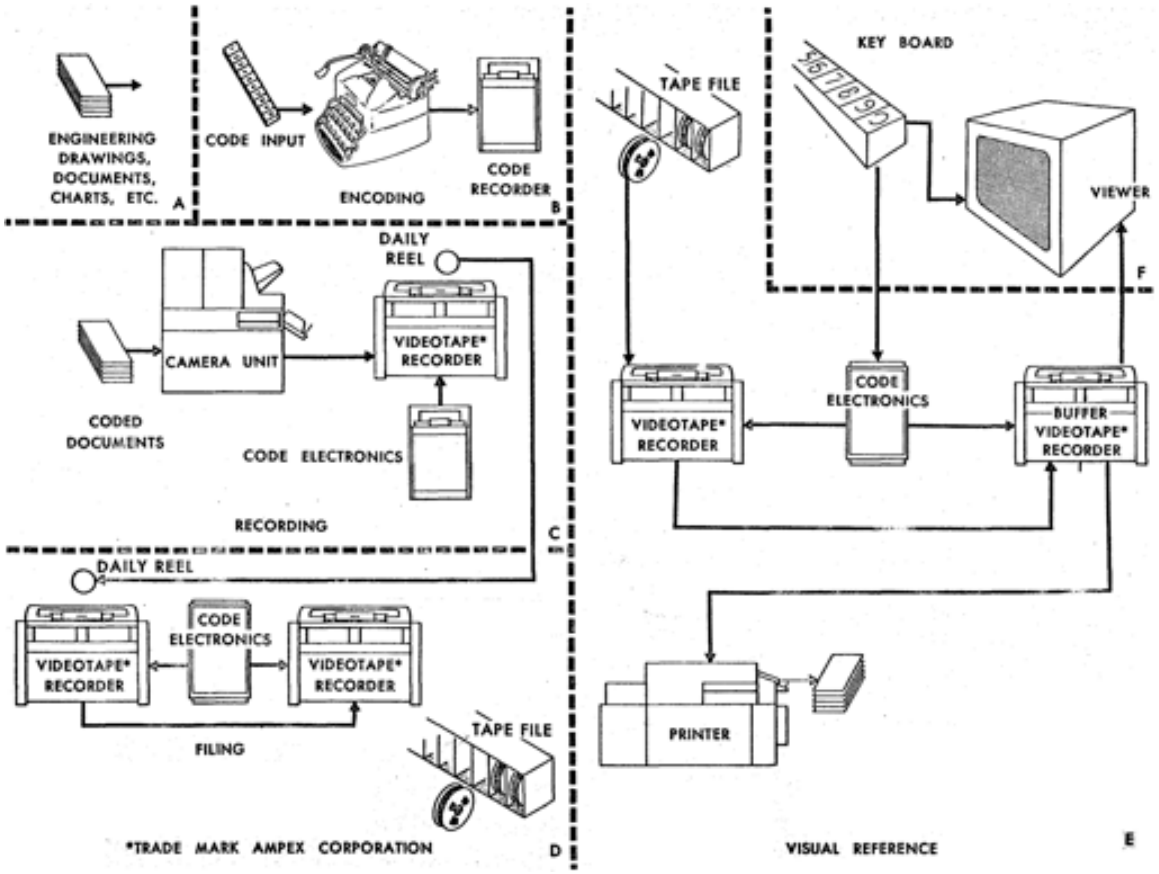
32 McQuade and Hammar, “Bing Crosby’s Magnetic Tape Revolution,” 156; Finn Jorgensen, “Instrumentation Recording on Magnetic Tape,” in Daniel, Mee, and Clark, *Magnetic Recording*, 317–318.

33 Ampex, *1957 Annual Report*, box 16, series 2, Ampex Corporation Records, p. 17.

34 Bugos, “Aerospace Impetus to Silicon Valley,” 102.

Magnetic tape thus became a medium for not only audio and video, but any kind of analog signal—any physical phenomenon electronically translated to a voltage and then translated again by an electromagnet to a magnetic field—as well as the discrete, quantized bits used by digital computers. "Science, industry, the military, education, medicine, and business have all felt the impact of the new technique," Ampex reported in 1959. "It filled a need in each of these fields for a more convenient, economical, and accurate means of storing, transferring, and analyzing information. This information might be in the form of a minute electrical signal emanating from the brain, radioed data on the flight of a missile, or the picture and sound of a television performance."[35]

Magnetic recording marks a point of continuity between categories of electronic media that we might otherwise consider distinct. The technology itself is not inherently analog or digital; the same tape, and the same tape recorder, can record either a continuous signal or a series of discrete bits. Indeed, early personal computers like the Apple II were designed to use audiocassette recorders as secondary storage devices alongside—or as cheaper alternatives to—floppy disk drives.[36]



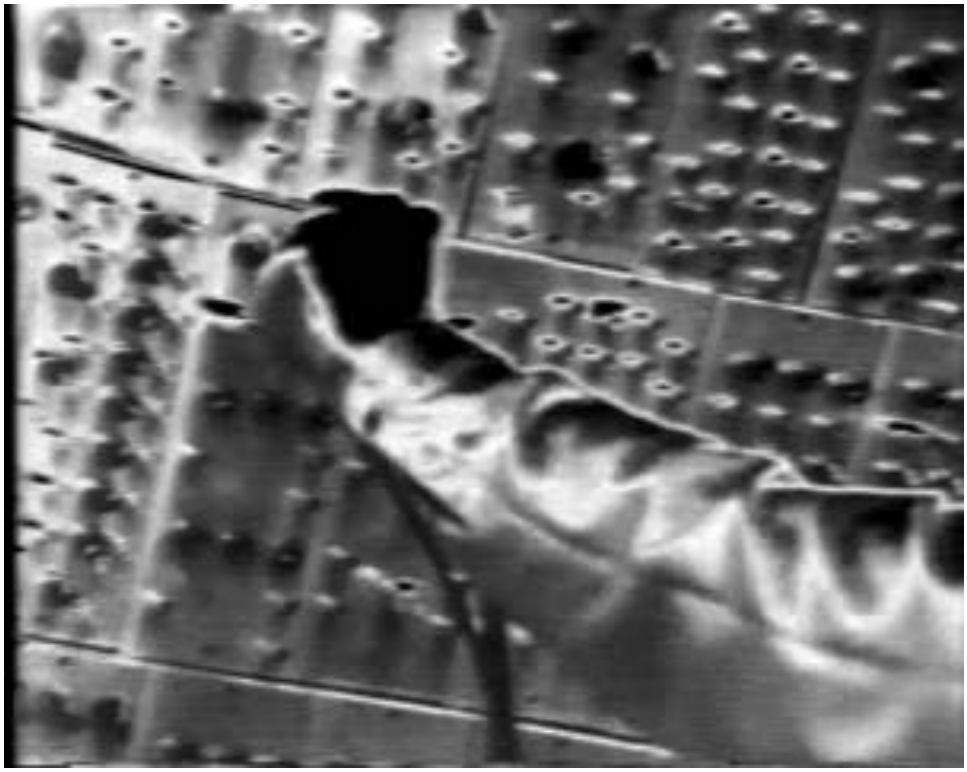
Ampex, "Videofile: A Micro Records Tool," August 20, 1964. Internet Archive, https://archive.org/details/bitsavers_ampexvideoMicroRecordsToolAug64_821285.

35 Ampex, *1959 Annual Report*, box 16, series 2, Ampex Corporation Records, p. 16.

36 *Apple II Reference Manual* (Cupertino: Apple Computer, 1978).

Even Ampex's efforts to enter the document storage industry, competing with technologies like microfilm, were split between analog and digital techniques. The Videofile, developed in the 1960s, stored images of documents as analog signals on magnetic tape, resulting in a medium analogous to microfilm as videotape was analogous to film. In a 1964 report, Ampex engineer Robert Miner estimated that each 8½ by 11 inch document, scanned at the relatively high resolution of 100 lines of vertical resolution per inch for legibility, would consume ⅝ inch of tape, and thus that a reel of tape could hold 135,000 pages of documentation. Because an image could be called up from tape remotely, he wrote, "Videofile employs television to bring information from the file to you; you don't have to go to the file." Ampex produced eight units for customers including Southern Pacific Railroad and Scotland Yard, which used theirs for storing fingerprints.[37] Miner soon went on to cofound Oracle Corporation and commercialize the now-ubiquitous relational database.[38]

In 1970, Ampex built another large scale storage system, the Tera-Bit Memory, which used dozens of reels of magnetic tape to store over a terabit (or 125 gigabytes) of digital data. "Customers of TBM were exclusively in the intelligence community and in other government agencies," writes John Mallinson. "Fewer than six systems were made."[39]



Dan Sandin, *Five-Minute Romp through the IP*, Chicago, 1973, video, 6:34. *Surveying the First Decade: Video Art and Alternative Media in the U.S., 1968–1980*, vol. 2 (Chicago: Video Data Bank, 1995), DVD.

37 John C. Mallinson, "The Ampex Quadruplex Recorders," in Daniel, Mee, and Clark, *Magnetic Recording*, 165–166; Ampex, "Videofile," 1, 4–5.

38 Mike Wilson, *The Difference between God and Larry Ellison: Inside Oracle Corporation* (New York: William Morrow, 1997).

39 Mallinson, "Ampex Quadruplex Recorders," 165–166.

Outside the domain of recording, analog techniques for electronic photography were often designed with explicit references to photochemical predecessors. When, in 1969, physicist and photographer Dan Sandin built his Image Processor—"a patch programmable general purpose analog computer, optimized for the real time processing of video images"—he modeled it not only on the Moog audio synthesizer but also, as Christine Tamblyn notes, on "photographic darkroom techniques: colorization, solarization, superimposition, burning and dodging."[40] The Image Processor was, in short, a computer for simulating photographic effects in real time, and like other video processing machines of its time it did so using analog techniques. A user could apply effects to an image on the screen by using knobs and patch cables to modify its electrical representation as a voltage inside the machine.[41]

The first consumer electronic still cameras, marketed in the 1980s, were a product of these analog traditions. Indeed, they were sometimes described as "still-video cameras," applications of the technology of video recording to the high-resolution still image. These cameras recorded analog signals on magnetic media such as floppy disks. Analog electronic cameras were quickly replaced by digital ones, and are now generally remembered only as a footnote to the abrupt digitization of the medium, but they in fact represent a distinct but closely allied history of making photography electronic, and recording it magnetically, using analog techniques.[42]

Sony Mavica still analog video camera prototype and its floppy disks, 1981. "Sony Mavica Prototypes (1981–1983)," Digital Camera Museum, http://www.digicammuseum.com/en/prototypes-rarities/item/sony-mavic.

The media players of the nineteenth century, such as the phonograph and the film projector, amplified patterns of light and vibration to create massive images and sounds. The new electronic media players of the twentieth century, in contrast, translated patterns of magnetism—

40 Phil Morton, Dan Sandin, and Jim Wiseman, "In Consecration of New Space" (Chicago, 1973), http://vasulka.org/archive/Artists4/Morton,Phil/ColorVidProcessor.pdf; Christine Tamblyn, "Image Processing in Chicago Video Art, 1970–1980," *Leonardo* 24, no. 5 (1991): 304.

41 Peter Sachs Collopy, "Video Synthesizers: From Analog Computing to Digital Art," *IEEE Annals of the History of Computing* 36, no. 4 (October–December 2014): 78.

42 William J. Mitchell, *The Reconfigured Eye: Visual Truth in the Post-Photographic Era* (Cambridge, Mass.: MIT Press, 1992), 17–18.

totally imperceptible to humans without such prosthetic assistance—into electricity and then into amplified images and sounds. This was the deep material transformation in media; digitization, the replacement of those continuously varying, analog patterns of magnetism and electricity with encoded, discrete digital patterns, is only a small part of the story. It consolidated the process of representing the image electronically and magnetically which began with the technologies of television and video.