Telecine

Telecine is the process of transferring motion picture film into electronic form, or the machine used in this process. Telecine enables a motion picture, captured originally on film, to be viewed with standard video equipment, such as televisions, video cassette decks or computers. “Telecine” is combination of “television” and “cinema.” Within the film industry, it is also referred to as a TK, as TC is already used to designate time code.

Basic principle

The telecine was invented to transfer motion picture film images into video signals. In all forms of telecine, light is projected through the film (whether negative or positive image) onto a pick-up device that translates the image into an electronic (or digital) video signal. This also allows the electronic (or digital) video signal to be processed and altered. See color grading for more information.

Flying spot scanner

The parts of a flying spot scanner: (A) Cathode-ray tube (CRT); (B) photon beam; (C) & (D) dichroic mirrors; (E), (F) & (G) red-, green- and blue-sensitive photomultipliers.

In a flying spot scanner (FSS) or cathode-ray tube (CRT) telecine, a pixel-sized light beam is projected through exposed and developed motion picture film (either negative or positive) at a phosphor-coated envelope. This beam of light “scans” across the film image from left to right to record the vertical frame information. Horizontal scanning of the frame was then accomplished by moving the film past the CRT beam. This beam passes through the film image, projecting it pixel-by-pixel onto the pickup (phosphor-coated envelope). The light from the CRT passes through the film and is separated by dichroic mirrors and filters into red, green and blue bands. Photomultiplier tubes or avalanche photodiodes convert the light into separate red, green & blue electrical signals for further electronic processing. This can be accomplished in “real time”, 24 frames a second (or in some cases faster). The Ursa (1989), the first in their line of telecines is capable of producing digital data in 4:2:2 color space. The Ursa Gold
(1993) stepped this up to 4:4:4 and then the Ursa Diamond (1997), which incorporated many third-party improvements on the Ursa system.\[4\]

CCD

The parts of a CCD scanner: (A) Xenon bulb; (B) film plane; (C) & (D) prisms and/or dichroic mirrors; (E), (F) & (G) red-, green- and blue-sensitive CCDs.

Rank Cintel (ADS telecine 1982) and Marconi Company (1985) both made CCD Telecines for a short time.

In a charge-coupled device (CCD) telecine, a “white” light is shone through the exposed film image into a prism, which separates out the image into the three primary colors, red, green and blue. Each beam of colored light is then projected at a different CCD, one for each color. The CCD converts the light into electrical impulses which the telecine electronics modulate into a video signal which can then be recorded onto video tape or broadcast.

In 1996 Philips working with Kodak introduced the Spirit DataCine (SDC 2000), which was capable of scanning the film image at HDTV resolutions and approaching 2K (1920 Luminance and 960 Chrominance RGB) x 1556 RGB. With the data option the Spirit DataCine can be used as a motion picture film scanner outputting 2K DPX data files as 2048 x 1556 RGB. In 2000 Philips introduced the Shadow Telecine (STE) this is a low cost version of the Spirit, with no Kodak parts. The Spirit DataCine, Cintel's C-Reality and ITK's Millennium opened the door to the technology of digital intermediates wherein telecine coloring tools were not just for video outputs, but could now be used for high-resolution data that would later be recorded back out to film.\[4\] The Grass Valley Spirit 4k (2004) replaced the Spirit 1 Datacine and uses both 2K and 4k line array CCDs.

Digital intermediate systems and virtual telecines

Telecine technology is increasingly merging with that of Motion picture film scanners; high-resolution telecines, such as those mentioned above, can be regarded as film scanners that operate in real time.
As digital intermediate post-production becomes more common, the need to combine the traditional telecine functions of input devices, standards converters, and colour grading systems is becoming less important as the post-production chain changes to tapeless and filmless operation.

However, the parts of the workflow associated with telecines still remain, and are being pushed to the end, rather than the beginning, of the post-production chain, in the form of real-time digital grading systems and digital intermediate mastering systems, increasingly running in software on commodity computer systems. These are sometimes called virtual telecine systems.

Frame rate differences

The most complex part of telecine is the synchronization of the mechanical film motion and the electronic video signal. Every time the video part of the telecine samples the light electronically, the film part of the telecine must have a frame in perfect registration and ready to photograph. This is relatively easy when the film is photographed at the same frame rate as the video camera will sample, but when this is not true, a sophisticated procedure is required to change frame rate.

In countries that use the PAL or SECAM video standards, film destined for television is photographed at 25 frames per second. The PAL video standard broadcasts at 25 frames per second, so the transfer from film to video is simple; for every film frame, one video frame is captured.

In the United States and other countries that use the NTSC television standard, film is generally photographed at 24 frame/s. Color NTSC video is broadcast at 29.97 frame/s. For the film's motion to be accurately rendered on the video signal, an NTSC telecine must use a technique called the 3:2 pulldown to convert from 24 to 29.97 frame/s.

3:2 pulldown

The process of converting 24 frame/s material to 29.97 frame/s is known as 3:2 pulldown. The term “pulldown” comes from the mechanical process of “pulling” the film down to advance it from one frame to the next at a repetitive rate (nominally 24 fps). This is accomplished in two steps. The first step is to slow down the film motion by 1/1.001. This speed change is unnoticeable to the viewer, and makes the film travel at 23.976 frame/s.

The second step of the 3:2 pulldown is the 3:2 (or 2:3, see below) step. At 23.976 frame/s, there are four frames of film for every five frames of NTSC video:

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\frac{23.976}{29.97} = \frac{4}{5}
\]
These four frames are “stretched” into five by exploiting the interlaced nature of NTSC video. For every NTSC frame, there are actually two complete images or fields, one for the odd-numbered lines of the image, and one for the even-numbered lines. There are, therefore, ten fields for every 4 film frames, and the telecine alternately places one film frame across two fields, the next across three, the next across two, and so on. The cycle repeats itself completely after four film frames have been exposed, and in the telecine cycle these are called the A, B, C, and D frames, thus:

Note that the pattern in this example is actually 2–3. A 3–2 pattern is identical to this except that it is shifted by one frame. For instance, starting with film frame B, followed by frame C, yields a 3–2 pattern (B-B-B-C-C). In other words, there is no difference between the two — it is only a matter of reference.

**Digital television, and high definition**

Digital television and high definition standards provide several methods for encoding film material. 50 field/s formats such as 576i50 and 1080i50 can accommodate film content using a 4% speed-up like PAL. 59.94 field/s interlaced formats such as 480i60 and 1080i60 use the same 2-3 pulldown technique as NTSC. In 59.94 frame/s progressive formats such as 480p60 and 720p60, entire frames (rather than fields) are repeated in a 2-3 pattern, accomplishing the frame rate conversion without interlacing and its associated artifacts. Other formats such as 1080p24 can decode film material at its native rate of 24 or 23.976 frame/s.