THE TIME BASE CORRECTOR: A STEADYING INFLUENCE

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March 1973 was a watershed year in the evolution of videotape production. At a National Association of Broadcasters conference it was announced that in terms of electronic newsgathering, videotape was faster, cheaper and had quicker turnaround time than film.[1] At the NAB convention that same month, Consolidated Video Systems debuted their CVS-500 time base corrector (TBC)(Figure 1).[2] It's immediate success won both CVS, Inc. and its inventor, Bill Hendershot, an Emmy award.[3] With the advent of this new technology, the digital age had arrived in television. How was this possible in the 1970s?


CVS 504B Time Base Corrector

Figure 1 – CVS 504B Time Base Corrector [4]

[1] Albert Abramson. *The History of Television, 1942 to 2000.* (Jefferson, NC: McFarland & Co., 2003), 149.

[2] Ibid.

[3] Diehl, Richard, "LabGuy's World: 1977 Ampex TBC-1 Direct or Heterodyne Color Digital TBC," last modified July 28, 2002.

[4] Bensinger, Charles. *The Video Guide.* 2nd Edition. Santa Barbara, California: Video-Info Publications, 1981, 7.

Up to this point in time, the main tape format used in broadcast production was 2" quad—a large, ungainly reel-to-reel videotape with an even larger record and playback system. Broadcast news departments still relied on 16mm film to capture current events and the length of time from production to air was painfully slow. By the 1970s, smaller video formats and portable equipment were making their way to the marketplace. These formats, most notably the cassette-driven ¾" Umatic, were all recorded and played back on helical scan video tape recorders (VTRs). As mentioned above, it was ideal for networks not only because it was cheaper and easily portable, but also it was breathtaking in its sheer speed of covering breaking news. However, there was a problem.

If a ¾" tape, for example, was recorded and played back in the same VTR there wouldn't be much of an issue. But suppose that same tape was moved to another VTR? In a perfect world, all analog VTRs would operate identically and tapes would play at a consistent speed. What happens instead is a time base error, which is a mechanical error that occurs as tape runs through the machine. These imperfections in both the tape and machine can appear as a waving image at the top of the screen known as "flagging", as a "skewing" error at the bottom of the screen, or as a horizontal "tearing" that appears throughout the picture.[5] Though using the skewing and tracking functions on the VTR to correct tape tension errors, it isn't enough to solve the problem. These distortions are further magnified when the tape is copied (dubbed) onto another tape. Time base errors become a larger problem

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[5] Erik Piil, "Time Base Error," *A/V Artifact Atlas,* last modified August 3, 2014, http://avaa.bavc.org/artifactatlas/index.php/Time_Base_Error.

when integrating more than one VTR and tape into an edit or studio playback.[6] Trying to produce effects such as dissolves and wipes with faulty signals through a switcher against a stable "house" signal (courtesy of a sync generator) will cause the picture to jump, jitter and roll (Figure 2).[7] According to F. V. Bucciarelli, "the residual time base error that is tolerable for numerous such applications is of the order of a few nanoseconds."[8]

Figure 2 – Time base errors.[9]

The time base corrector, when connected to a VTR, strips the video signal's horizontal and vertical sync pulses and replaces them with clean, stable pulses. When partnered with a processing amplifier (proc amp), it also allows the user to set video (luminance), set-up (black/pedestal), chroma and hue levels to match

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[6] Robert L Hartwig. *Basic TV Technology.* (Boston, Massachusetts: Focal Press, 1990), 90.

[7] Ibid.

[8] F.V. Bucciarelli. "A Digital Synchronizer for a Videotape Recorder." *Journal IEEE (first ITW conference of the year) Information Theory Workshop (ITW)* 61, no. 4 (April 1973): 506.

[9] Erik Piil, "Time Base Error," *A/V Artifact Atlas,* last modified August 3, 2014, http://avaa.bavc.org/artifactatlas/index.php/Time_Base_Error.

NTSC broadcast standards.[10] When the video signal enters the TBC, it initially goes through an A-to-D (analog to digital) converter. Paul Hartwig describes the conversion into digital from signal to numbers succinctly:

> The video signal is up to .7V, and that the stronger the voltage (.7) the brighter the glow on the CRT; the weaker the voltage (.00) the darker the CRT. If we picked a point right in the middle of that range (.35V), we could probably figure out that that would be in the middle of the gray range. This is sort of what the A-to-D converter does. The brightness range is divided into 256 possible levels with .00V equaling the 0 level and .7 equaling level 255. Midway through the voltage range (.35V) would also be midway through the number range (127). As a result each of the 256 numbers represents a separate and distinct voltage and brightness.[11]

Hartwig goes on to explain that the video information is sampled and quantized. This means that by sampling, a piece of video is grabbed and held and by quantizing the sampled information is changed into a number.[12]

> How often a sample is taken is very important. How often the video is sampled will differ between various makes of equipment, but it will always be a factor of the color burst frequency (3,579,545 Hz). Normally, either three times or four times the color burst frequency is used. In either case, each line of video will be sampled and quantized several hundred times.[13]

After this process has taken place, the digitized video leaves the A-to-D converter as a stream of numbers.[14] The digital video is stored in memory for a brief period of

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[10] Gary H. Anderson. *Video Editing and Post Production: A Professional Guide, 2nd Edition.* (White Plains, New York: Knowledge Industry Publications, Inc., 1988), 75.

[11] Hartwig. *Basic TV Technology,* 112.

[12] Ibid.

[13] Ibid.

[14] Ibid., 114.

time (microseconds) and is only released by horizontal sync pulses produced from the sync generator. Because digital video cannot be integrated with analog video, it ultimately has to go through a D-to-A (digital to analog) converter (figure 3).[15]

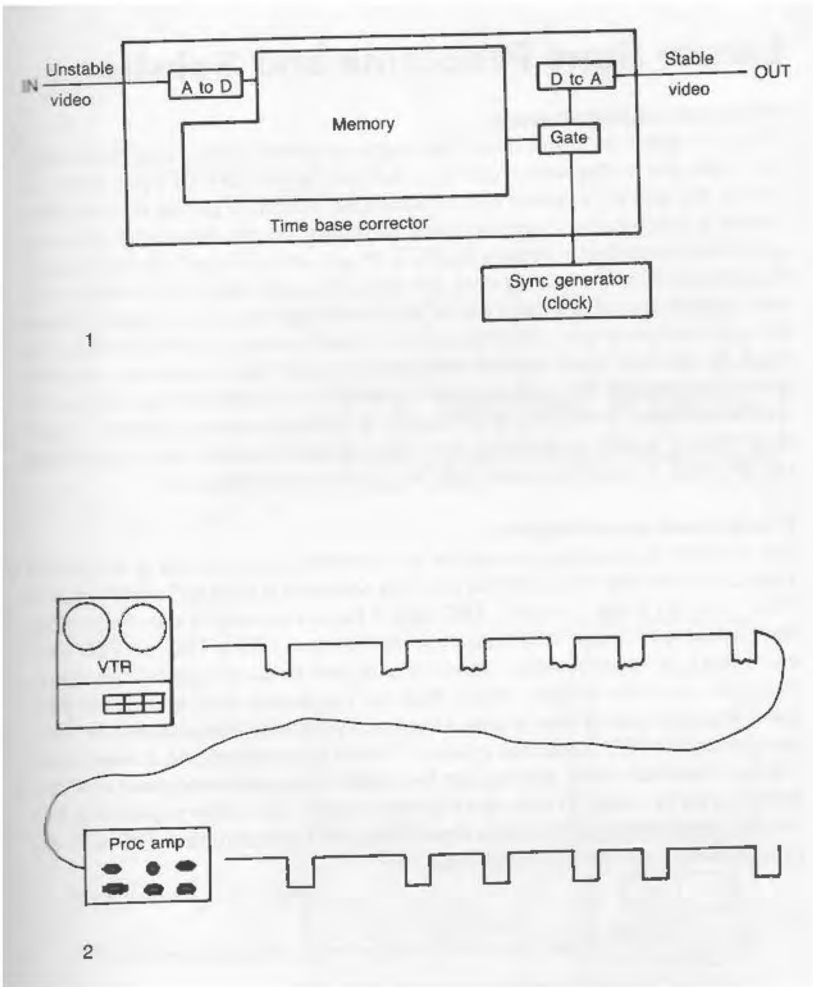

Figure 3 – Time Base and Proc Amp correction processes.[16]

Time base correctors have a "window of correction" which estimates the amount of time base error it can correct.[17] Earlier models were only capable of correcting a

[15] Ibid.

[16] Ibid., 115.

few lines at a time. Later models with greater memory were able to correct up to one field at a time (262.5 scan lines). These were known as "infinite window" TBCs.[18] There were also some TBCs that offered dropout compensation. Dropout refers to the flaking of the metal or iron oxide particles that coat the videotape. This occurs due to repeated tape playback and the natural wear and tear that occurs as the video ages. Creases in the tape surface can cause dropout as well. It appears as a white line (or, in television parlance, a "hit") flashing across the picture. The dropout compensator in the TBC corrects dropout by replacing the damaged scan line with the line scanned before it.

Stand-alone units were eventually combined with a frame synchronizer (frame sync), a device with a larger memory capable of storing and stabilizing frames of video. Usually found in broadcast studios, they were highly effective in locking live broadcast signals, such as remote cameras and satellite feeds, to the studio's synch generator. By the mid to late 80s, VTRs were manufactured with built-in TBCs. Sony Betacam PVW and BVW series both had TBCs built into their VTRs as well as level controls. Even their Umatic 900 and 9800 series had optional built in TBC cards available. Ampex also had a line of TBCs to complement their 1" machines. As Gary Anderson notes in *Video Editing and Post-production,* "Any multiple-VTR system that is capable of performing dissolves needs one TBC per playback VTR to ensure stable video transitions and edits."[19]

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[17] Ibid.

[18] Ibid.

[19] Anderson. *Video Editing and Post Production,* 75.

Besides partnering with the frame sync, time base correctors also work with other devices to produce a clean signal. As mentioned earlier, a centralized sync generator, also referred to as house sync, provides broadcast or post-production facilities with a stable pulse to which all devises can genlock. The sync pulses of all devices, such as VTRs and cameras, are timed to precisely match those of the sync generator. Proc amps are included with a professional level TBC. As mentioned earlier, this device is responsible for setting video, set-up, chroma and hue levels. Proc amps are also capable of correcting unstable VTR signals by reshaping and reinserting sync pulses (see figure 3).[20] Switchers are also important when working with a TBC. They allow the user to compare the color bars between the house-generated bars and the recorded bars coming from the source tape and set levels and sync, if needed. None of these tasks can be accomplished without a waveform monitor and a vectorscope—two devices that display different aspects of the video signal and assist the user in determining if the signal falls within broadcast standards. The waveform monitor displays the luminance and set-up (levels) and, when the flat display is chosen, will also indicate chroma saturation. The vectorscope is solely concerned with displaying the video's chroma and hue levels.

Who used time base correctors? A wide variety of industries and consumers from networks, industrial and educational facilities to video enthusiasts looking to build a high-end edit suite in their homes. In a 1974 article in *Educational and Industrial Television*, Eric Somers praised the TBC saying they "somehow magically

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[20] Gerald Millerson. *Video Production Handbook.* 3rd Edition. (Woburn, Massachusetts: Focal Press, 2001), 275.

transform signals from low-cost video recorders into signals which meet the stringent FCC broadcast requirements" and that it "allows the educational and industrial producer to reach new standards of technical quality."[21] This combination of high quality at a low cost was highly appealing to networks that were eager to invest in formats such as Umatic for their news departments. TBCs were mounted in broadcast studios, edit suites, and tape operations for playback and recording. They were used for on-air playback, camera operations, recording satellite feeds, dubbing and video editing.

For example, in a news editing suite with one playback VTR, when a source tape came in from the field, the first thing an editor would do upon inserting the tape in the machine was to play back the color bars recorded at the top of the tape. Using a waveform monitor and vectorscope as a guide, the editor would adjust levels using the video and set-up knobs on the TBC—7.5 IRE for set-up and 100 IRE for video. With the waveform monitor in flat display, the chroma could also be adjusted making sure that the yellow and cyan bars do not exceed 100 IRE. Then, the editor checked chroma and hue levels with a vectorscope. Using the chroma and hue knobs, the editor adjusted the signal until each representative color on the color bar test pattern (red, green, blue, cyan, magenta and yellow) are situated within their target boxes on the scope.

If the edit suite contained multiple playback VTRs and a switcher, the editor compared the color bars from each tape in each VTR against the color bars that were

[21] Eric Somers. "The Time Base Corrector." *Educational and Industrial Television* 6, no. 8, (1974): 13, 27.

coming from the switcher. Selecting either the “Cut” button or the “Mix” button and dissolving between the two bars, the editor operated the TBC the same way as mentioned above. The difference this time is the editor made sure that the transitions between the playback machines and the generated bars from the switcher were smooth. If there were any sudden bumps or color phase shifts, the timing was off and the editor used the sync function on the TBC to synchronize the playback machine with the house sync. The editor magnified the horizontal sync on the waveform monitor and lined up the edge of the front porch on one of the vertical hatch marks. Inserting a small screwdriver into the sync function on the TBC, the editor rotated it in minute increments while using the switcher to cut between color bars until the front porches of both lined up exactly on the same hatch mark. The same process was used when timing out a broadcast studio. At the end of this procedure, you had an edit suite or a studio that was “timed” by the TBC to match the internal sync generator, producing a consistent video signal that was compliant with NTSC standards.

How did analog video ever manage error-free playback before the time base corrector came along? Ampex created a solution to the time base error dilemma for 2” quad machines in the early 60s. The first was an Amtec (Ampex Timing Error Compensator), an analog device used for black and white VTRs and later on, as black and white was replaced by color, a Colortec.

> AMTEC consisted of a lumped delay line of series inductors and parallel capacitors in the form of varactor diodes. A varactor diode is a special device that, when reversed biased, behaves like a capacitor. Better yet, its capacitance can be varied quite a bit by varying the applied voltage. The time it takes a signal to pass through the delay line can be varied and controlled very precisely by the applied control voltage. By passing the

> playback signal through this delay line, and simultaneously varying the control voltage in the opposite direction to the video's time base error, a time restored signal is reproduced.[22]

This system, however, did not work for color. The "corrector was followed by a further delay line through which the signal was passed but this time the delay was controlled by comparison of the reproduced burst and a standard subcarrier."[23] Both systems worked well for quad, a system based on transverse recording and known for stable playback. It would not have worked as well on the less reliable helical scan record and playback systems, but by the time they came to market, a digital solution was available.

From the 1970's to the millennium, the time base corrector was in constant use. Even with the advent of digital based media such as Sony's Digibeta, there was still a need for a TBC to correct the time base error inherent in the mechanical inconsistencies of the machines as well as to compensate for any imperfections that existed in the tapes themselves. In the experience of this author, TBCs were still being used in edit suites as late as 2013. But under these circumstances, they were mostly used to play back older footage.

By the beginning of the 1990s, a new digital revolution was starting to take place. The Avid/1 editing system was replacing the traditional method of physically cutting film. It was only a matter of time before digital, non-linear editing systems

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[22] Richard Diehl, "LabGuy's World: 1977 Ampex TBC-1 Direct or Heterodyne Color Digital TBC," *LabGuy's World:The History of Video Tape Recorders Before Betamax and VHS,* last modified July 28, 2002, http://www.labguysworld.com/Ampex_TBC-1.htm.

[23] White, Gordon. *Video Recording: Record and Replay Systems.* (London: Butterworth & Co., 1972), 72.

took over broadcasting as well. There were also digital tapes and VTRs on the market as well, such as Panasonic's DVCPro. These machines did not generally need a TBC, but a proc amp was still included to adjust levels. However, as long as older formats such as betacam were in use for recording and playback, the TBC was still in demand.

That began to change around the early to mid 2000s when tapeless video technology became widely available. With digital cameras, it was possible to record direct to disk or flash memory making a VTR unnecessary. The digital images captured were free from any mechanical imperfections that could have occurred had they been produced on helical scan tape and run across a record head through a camera deck or VTR. No matter how many times a digital video file was copied, there was no generational loss and no magnification of any errors like those that appeared in a straight tape-to-tape dub without a TBC to steady and correct the image. A digital copy was a perfect clone of the original. This ultimately led to the obsolescence of the time base corrector.

With the inherent perfection of digital formats and the push to reformat all video to digital, the question is why does the time base corrector need to be preserved? There are pros and cons to this question that deal with the short- and long-term preservation of helical scan tape.

On the plus side, the TBC is the only device that will allow the archivist or conservator to play back a helical scan tape with clean sync pulses correcting any time base errors, be it ½", ¾" or 1" formats. Playing back a tape without one will make preserving a tape through reformatting to a similar tape format impossible, as the image will be highly unstable and unusable. A stand-alone TBC is worth preserving as much as one that is built into a VTR since there are extant, working versions of early VTRs still in use that do not have TBCs as part of their operating systems. If conservators and archivists are committed to the long-term preservation of videotape, the TBC is an integral part of its survival.

Conversely, there is the school of thought that videotape is a format that is at risk and in danger of extinction in the next twenty years. The fragility of the medium, from demagnetization of the tape to iron oxide dropout and the dreaded sticky shed syndrome, make saving the material housed on the various video formats a matter of great urgency. The question that looms over this crisis is what is the best method of preserving video? Is it best to preserve the original tape stock on which the material was recorded or copy to another format? There is a great push to digitization, but that format is turning out to be just as fragile as videotape, even though many institutions are leaning in that direction. For the short-term push to reformat videotape, the TBC once again is an invaluable part of the equation. It puts one in mind of those large, indestructible musical disks that played in music boxes made of glass and wood. Without the delicate instrument to play back the disks, all that is left is a large and useless hunk of metal.

Bibliography

Abramson, Albert. *The History of Television, 1942 to 2000.* Jefferson, NC: McFarland & Co., 2003.

Albert Abramson gives a blow-by-blow historical account of how each new technological innovation came to market and what its impact was. His accounts of the 1973 NAB conference and convention and the reactions to the debut of the TBC were the most specific found in any publication.

Anderson, Gary H. *Video Editing and Post Production: A Professional Guide, 2nd Edition.* New York: Knowledge Industry Publications, Inc., 1988.

This is a timely guide for editors working in the industry at the end of the 80s. Anderson covers all aspects of postproduction from offline to online and analog to digital. He clearly describes how a TBC is used in a postproduction environment.

Bensinger, Charles. *The Video Guide.* 2nd Edition. Santa Barbara, California: Video-Info Publications, 1981. http://videopreservation.conservation-us.org/vid_guide/index.html.

This guide was written during the heyday of the TBC. This e-book is a wonderful source for a basic history of video production. The photos of the video equipment were very well rounded and did a great job illustrating and highlighting the text.

Bucciarelli, F.V. "A Digital Synchronizer for a Videotape Recorder." *Journal IEEE (first ITW conference of the year) Information Theory Workshop (ITW)* 61, no. 4 (April 1973): 506-507.

This paper published in the *IEEE Journal* is one of the earliest articles published on the idea of a Time Base Corrector though it is referred to as a Digital Synchronizer. This article has a wonderful description of time base errors and is technically specific in its solution.

Diehl, Richard, "LabGuy's World: 1977 Ampex TBC-1 Direct or Heterodyne Color Digital TBC," *LabGuy's World:The History of Video Tape Recorders Before Betamax and VHS,* last modified July 28, 2002, http://www.labguysworld.com/Ampex_TBC-1.htm.

An excellent "museum" site dedicated to the video equipment of yesteryear. Diehl is an able guide and historian as he describes not only the inner workings of a TBC, but also discusses at length its predecessors, the Amtec and Colortec.

Hartwig, Robert L. *Basic TV Technology.* Boston, Massachusetts: Focal Press, 1990.

This book explains the digitization process of a TBC clearly, succinctly and in layman's terms. The illustrations were also very helpful in detailing the process.

Millerson, Gerald. *Video Production Handbook.* 3rd Edition. Woburn, Massachusetts: Focal Press, 2001.

For this 2001 edition, the TBC was still a viable device used in the industry and featured under the compensatory/corrective equipment section of the book. Millerson provides a good commentary about the similarities and differences between a TBC and a proc amp and why TBCs include them in their packaging.

Piil, Erik, "Time Base Error," *A/V Artifact Atlas,* last modified August 3, 2014, http://avaa.bavc.org/artifactatlas/index.php/Time_Base_Error.

The *A/V Artifact Atlas* site is a helpful tool in identifying errors that occur in both digital and analog video from artifacts to time base errors. It provides a simple description and illustrations of the different types of time base errors.

Somers, Eric. "The Time Base Corrector." *Educational and Industrial Television* 6, no. 8, (1974): 12-27.

This article from the early 1970s extolling the virtues of the TBC was handy not only as a historical look at how the TBC was perceived in the industry when it appeared on the market, but it also explains very clearly how they work. The article came with supplemental sections on how to differentiate between the different TBCs and a directory of which TBCs were for sale at that time.

White, Gordon. *Video Recording: Record and Replay Systems.* London: Butterworth & Co., 1972.

An older publication that deals with recording a variety of tape formats. It had a very helpful section describing the Amtec and Colortec system and how they were used in recording 2"quad video.