DIGITAL INTERMEDIATE

BY: Steve Wright

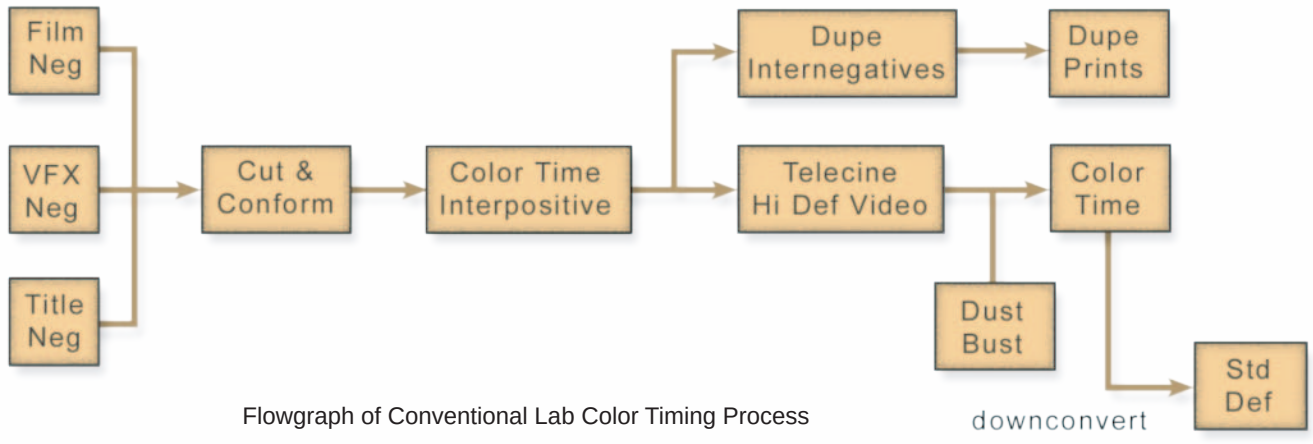
September 2004

The feature film industry is now engaged in the rapid "digitization" of its entire production process, first starting with the off-line editing of movies in 1989, then proceeding through the introduction of digital effects shots in 1992, to the digitizing of the entire feature film for Digital Intermediate color timing in 2000. The digitization of the movie industry will be complete with the digital capture of the original movie and digital cinema projection in the theatres, both of which are now on the visible horizon. This white paper offers an overview of the Digital Intermediate process for today's feature films.

The Conventional Lab Process

If the original camera negative for a movie were simply edited together, printed and projected, there would be annoying "pops" in brightness and color from shot to shot. The film industry solved this problem decades ago with a process called color timing, in which each shot of the movie is color corrected to match its neighboring shots. This is done by first editing the original negative into reels of 1000 or 2000 feet, then re-photographing them onto an intermediate film stock called an inter-positive (IP). During this re-photographing process the timing of the red, green, and blue lights used to expose the IP are adjusted on a shot-by-shot basis to even out the brightness and color. This color-timed IP is then duplicated several times onto another intermediate film stock called an inter-negative (IN,) which is in turn used to strike the thousands of prints projected in the theatres. Awkwardly, even though titles and any visual effects shots are now typically produced digitally, for lab color timing they must first be filmed out, then cut into the edited negative.

Beyond simply smoothing out variations in the original photography, the color timing process also has a very important artistic component. The overall brightness, contrast, and color of a scene also carry emotional impact, and colorists use this to add to the entertainment value of a movie by giving the movie a "look". For example, scenes can be colored cool (bluish) or warm (yellowish/reddish) to evoke certain feelings in the viewers. Color timing a movie is a high art form and considered a key part of the creative process of filmmaking. Lab color timing, however, only produces the color timed version of the feature film, but no video masters. To create the 24P Hi Def video master, a separate telecine process is done at a later date to transfer the color timed film to video; then the color timing is revised for video viewing.



Flowgraph of Conventional Lab Color Timing Process

The Digital Intermediate Process

The Digital Intermediate (DI) process has become practical due to recent advances in computer technology that have dramatically lowered the cost of digitally color timing an entire feature film. While technically feasible as early as 1992 -- when Kodak first released its Lightning film scanners and film recorders -- attempting to scan, color time, and record an entire feature film would have cost over one million dollars and taken several months. Today a DI can be done in a few weeks at the cost of a couple hundred thousand dollars.

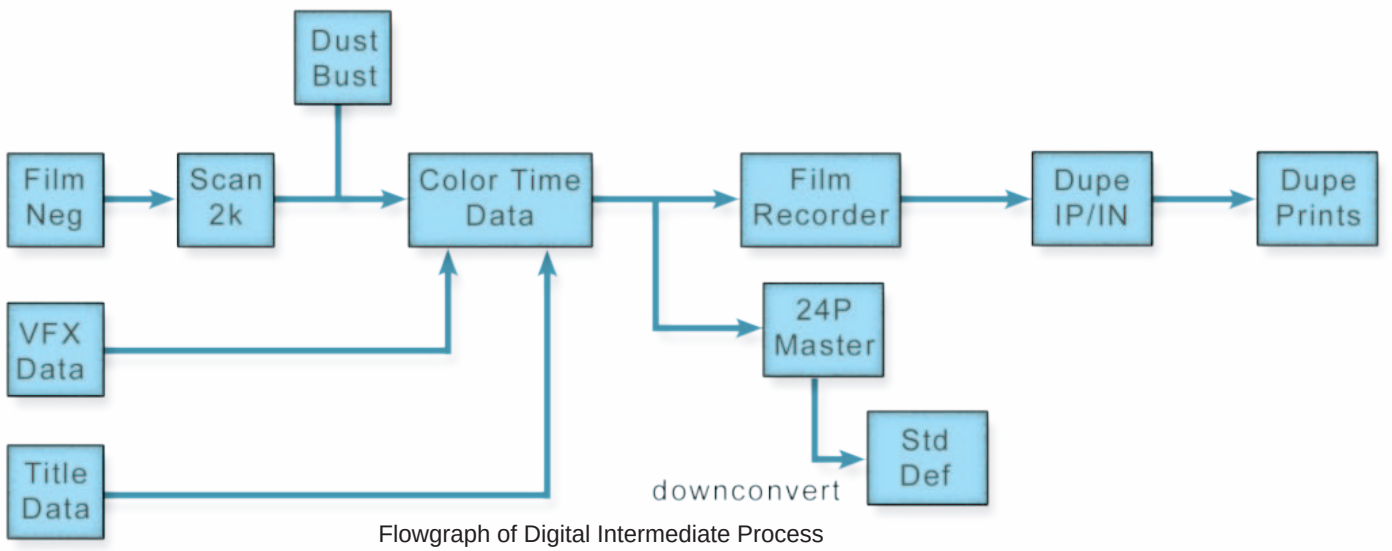
The first step in the DI process is to digitize the entire feature film. After the picture is "locked" (all editing decisions have been finalized) the selected cuts of the original camera negative are edited together into several reels. The titles and any visual-effects shots are "slugged" into the negative as black frames, which are used as place holders since these elements are now typically generated digitally. Later, they will be loaded as digital files and added to the main picture negative scans during the color-timing process.

The edited negative reels are placed on film scanners to digitize the entire reel as one continuous piece of film. The film is typically scanned at 4k resolution (4096 x 3112) or higher, then resized down to 2k (2048 x 1556) for color timing. 2k resolution offers a good compromise between reasonably sharp images and reasonable data size. The digital film frames are then dust-busted (scanned dirt is painted out) and brought into the computerized color-timing system in a coloring suite, which performs the actual color corrections.

Once in the coloring suite, the digital colorist has vastly more control over the image than with conventional lab timing. The lift, gamma, and gain can be adjusted individually for the red, green and blue colors, or the overall picture. Even the contrast and saturation can be changed. The digital colorist can even isolate selected regions of the picture, such as skin tones or the sky, to receive special treatment while leaving the rest of the picture unchanged. Taken together, this allows for far greater control and creative freedom as compared to conventional lab timing that is limited to adjusting the overall exposure of the red, green, and blue colors.

The client may attend the color-timing sessions full time, or just stop by periodically to review progress and make comments. The work in progress is viewed on a large screen using a high-resolution video projector that is carefully calibrated to match the look of the finished projected film. How well this video projector "tracks" color with the projected film is one of the most important aspects of the color science used in the DI process. The projected film in the screening room must obviously look exactly like the video projection in the color-timing suite for the color decisions to be valid.

The last step in the process is to film-out the finished color-timed movie on an intermediate film stock. During the color timing process (which may go for several weeks), there have been short test filmouts and screenings to confirm that the film matches what has been seen on the video projector in the coloring suite. Once the client is satisfied with the look of the first reel, it is filmed out as one continuous negative on a film recorder. These can be 1000 or 2000 foot



Flowgraph of Digital Intermediate Process

reels, depending on the capacity of the film recorder. *It is this digitally color-timed negative that is the digital intermediate.*

While the description above outlines the steps in sequence, in practice the actual workflow is more parallel. For example, the first reel to be filmed out might be reel 5 because it was the first reel to be locked. At the same time reel 5 is being filmed out, the colorist might be color-timing reel 2, while reel 4 is in being scanned.

Auto Conforming

In the DI process outlined above, the camera negative was already edited together into conformed reels that were then scanned and color timed as a finished reel. Conforming is simply the process of cutting the original camera negative into separate shots and splicing them together to "conform" them to some master editing list. The process described above would properly be called the conformed negative process since each film reel was already conformed when it was scanned.

The Digital Intermediate process, however, creates the possibility of doing an auto conform where the movie is actually conformed during the DI process itself. With the auto conform method, the original camera negative is never cut. Instead, each original camera roll is placed in tact on a film scanner and only the shots to be used in the final edit are scanned. The scanned frames are then assembled in the proper order by the computer during color timing to conform to the final edit of the movie. To perform this minor miracle, the computer uses the EDL (Edit Decision List) that was generated by the off-line editing system to automatically conform the entire movie - hence "auto conform".

The two main advantages of auto conforming are that the original camera negative is preserved in tact and that the editing changes suggested by a preview test screening become quick and easy. Keep in mind that when the negative is cut to edit a shot into the movie, one frame on each end of the shot is destroyed to make the splice. At a later date, that shot could be re-cut to be shorter, but not longer. With the auto conform method, providing the new edit points is all that is needed; a new version will be automatically reassembled. Auto conforming introduces a whole new level of editorial freedom.

Digital Mastering

One of the major side benefits of the DI process is the ability to immediately create a very high-quality Hi Def video master (and even a Digital Cinema version) directly from the same data files as the feature film. With the conventional lab process, the color-timed film must be digitized at a later date on a telecine and all of the color timing revisited for video. By this time, the director and cinematographer are often off on their next project and not available to supervise the video-color timing. It is a more efficient and higher quality process to take the color-corrected DI film data and convert it video than to directly lay off tape.

The emerging standard for this Hi Def video master is 24P, which is the 24 frame per second progressive scan format (of the many Hi Def video formats). The virtue of the 24P format is that all other Hi Def and Standard Def video formats can be derived from it in a simple, quick, and lossless way. When down-converted to Standard Def it even becomes the master for the DVD. When the Hi Def video master (and perhaps a Digital Cinema version) is included in the DI process, the entire process is then referred to as Digital Mastering.

The Equipment

Not surprisingly, the DI process requires a great deal of very expensive equipment. Film scanners and recorders cost hundreds of thousands of dollars each. There are massive disk arrays required to hold the three-to-four terabytes of data required for an entire feature film, multiplied by three or four films, plus the actual color-timing computer system itself. The color-timing computer systems fall into two categories - hardware-based and software- based - each with its own advantages and disadvantages.

The main advantage of hardware-based systems is that it can display the color-timed picture at high resolution in real time. Their speed comes from using dedicated hardware circuits for the color-timing and resizing operations, making them much faster than general purpose computers. Their disadvantages include: Very expensive, short list of features, new features can only be added by purchasing expensive new logic boards from the manufacturer, and fixed upper limit on image resolution (currently 2k). All of these restrictions are necessary for their real-time operation.

The software-based systems have all their color-timing and resizing operations programmed into software that runs on "commodity" hardware, i.e. generally available computers. They are not as fast, but do not suffer from the many other limitations of hardware-based systems. They advantages are noteworthy: Far less costly to purchase, long list of features that can easily be expanded, and "resolution independent", which means that they can work on any image size, such as 4k resolution or beyond.

The speed limitations of software-based systems can be somewhat overcome by working with proxies and parallelizing the work load. Proxies are half or quarter size versions of the original film scans, which the computer can process much faster so that the colorist can still work in real time. After the color decisions are made, the system then renders the color-timed images at high resolution in the background. By parallelizing the workload, several workstations can be simultaneously working on different stages of the movie so that the schedule is kept short

.

Advantages of Digital Intermediate?

Creative Control - Once the film is digitized into the computer there is almost no limit to what can be done creatively, while the options in the conventional lab process are sharply limited. A shot can even be recomposed (reframed) by zooming in and repositioning.

Targeted Regions - The DI color correctors have the ability to target specific regions of the picture, such as the skin tones or the sky for special treatment. Again, all of these effects can be restricted to just the areas of interest without affecting any other parts of the picture.

Special Processing - Once the movie is digitized into the computer there is a long list of additional operations that can be done to the film data. For example, de-grain or re-grain a shot, eliminate flicker, sharpening, remove a scratch, stabilize a shot, or re-time (speed change) a shot. Many production problems can easily be fixed during DI with special processing.

Digital Reformatting - Many films today are initially shot as super 35 then digitally reformatted during the DI process to their final academy aperture for theatrical release. Where this really pays off is for a super 35 2.40 extraction to Cinemascope. The movie can be filmed using normal spherical lenses to avoid using the difficult and expensive anamorphic lenses required to film in Cinemascope.

Digital Titling - Doing the titles digitally is cleaner and crisper, does not introduce "gate weave," and the titles can be given many different looks and treatments by the computer at a reasonable cost.

Auto Conform - It is the ability to do a DI that made auto conforming possible. Without digitally assembling the scanned shots of a movie, the original camera negative must be cut up and spliced together which, of course, destroys the frame of film at each end of the cut.

The 24P Master - Since the color-timed digitized film frames are already in the computer, a superb quality 24P Hi Def video master can be made at essentially the same time as the feature-film DI for very little additional effort.

The Future

One aspect of the DI future can easily be predicted simply by tracing the normal evolution of computer technology. Faster film scanners and film recorders will lower the cost of scanning and recording as well as shorten schedules. Faster and cheaper disk arrays and color-timing computer systems lower the cost and shorten schedules yet again. The inexorable march of technology's progress will continue to lower the cost and reduce the time required for doing a DI for the foreseeable future.

It is still fairly expensive and time consuming to film out the finished color-timed negative, so it is usually filmed out only once. The digital negative then has to be taken to the lab to make the inter-positives and the inter-negatives used to reproduce the thousands of prints for the theatres. Soon it will be cost effective to film out five or ten digital negatives, which can then be directly used to make the release prints for the theatres. This will save two generations of film duplication and make for much better looking prints for the theatres.

Faster and cheaper film scanners will make another dream of the DI process a reality, namely the "scan once" paradigm. Currently the film is actually scanned twice - first on a telecine at video resolution for the video dailies, then again at high resolution for the actual DI. Scanning the film at high resolution

is expensive, so only the final shots to be used in the movie can be scanned. Once film scanning becomes fast and cheap enough, all of the potential shots that might be used in the movie can be scanned at high resolution. The video dailies and the final DI will then be made from the one set of scans.

The 4k DI will be here soon. While the film scanners and recorders can all work comfortably at 4k today, it is all of the "data wrangling" in between that makes working at 4k too costly. Another resolution bottleneck is the hardware color correctors, which are limited to 2k to maintain their real-time performance. The software color correctors, however, can handle an honest 4k data stream and already a few DI jobs have actually been done at 4k in spite of the current time and cost penalties.

One of the most exciting future trends will be the addition of digitally enhanced "looks" and "treatments" for feature films. The current artistic efforts are to simply replicate lab generated looks (color timing, bleach bypass, push or pull processing, etc.). At some point, filmmakers will realize that we need not confine the looks and treatments to replicating what can be done in a lab. The full range of image processing capabilities that the computer brings to the film making process will then be tapped for a virtually unlimited creative palette for filmmakers.

Conclusion

Two things are becoming perfectly clear about the DI process. First, when you consider the aggregate time to produce the color-timed feature and the digital masters, the DI process is becoming faster and more cost effective than conventional lab timing. It is an intrinsically more efficient way to finish a feature film, and in the end, time-to-market and production flexibility are keys to controlling cost.

Second, that the Digital Intermediate process is both an artistically and technically superior way to finish a feature film. It dramatically increases the creative palette of the filmmaker and offers many technical and quality advantages for mastering to other formats (video, DVD, Digital Cinema, etc.). Software-based systems have the low cost and flexibility that enables quick response to the rapid developments in technology, as well as the creative demands of today's filmmakers. Future filmmakers will quickly learn to take full advantage of DI's rapidly evolving potential because creativity always expands to fill the technology.