# The Quantel Guide to Digital Intermediate

edition one

Quantel

# The Quantel Guide to Digital Intermediate

# Foreword by David Jeffers, The Moving Picture Company

## The Magic of the Movies…

For well over a century – from the earliest moving images of the zoetrope, followed by the silent movies, the talkies, the arrival of glorious Technicolor, the introduction of wide screen cinematography and Dolby sound, to the revolution of digital film – the magic of the movies continues to endure.

As cinema audiences and revenues all over the world continue to grow, today's film fan has never had it so good with cinematic imagery that is unrivalled in its wonder, quality and sophistication. The application of digital film technologies to film production has raised the bar of creativity and production value to a level never previously experienced; today's filmmaker is at the forefront of the digital film revolution.

Although the earliest digitally generated film imagery began to emerge in the late '80s, it wasn't until Stephen Spielberg brought the real life terror of dinosaurs in 'Jurassic Park' to the screen in the early '90s that the full impact digital VFX in film became apparent. Throughout the '90s digital VFX technologies grew in tandem with the ambitions of filmmakers resulting in a whole genre of movie making that has become synonymous with the world of digital film. From the seemingly impossible task of creating James Cameron's frighteningly realistic 'Titanic' through to the unimaginable fantasy worlds of the new generation 'Star Wars' series, digital film has enabled the creation of imagery never before thought possible.

And just as the professionals and the cinema going public thought it had all 'been done' so comes along the block busting digital achievements of 'The Harry Potter' sagas, 'The Lord of the Rings' and 'Matrix' trilogies. With the digital landscape in film continuing to broaden, the practitioner finds him / herself with an ever-increasing range of tools that extends the possibilities of cinematography.

Extending beyond the world of digital VFX, digital intermediate enabling technologies have opened creative possibilities that were once the preserve of the television industry. Creative colour timing in the digital domain is now a reality and providing the first truly interactive experience for the cinematographer to realise the vision of his / her film. Encouragingly, the take up of this post production technology is now being enthusiastically embraced by the industry at large, having been pioneered by the enthusiasm of the smaller budget feature filmmakers. Quick to identify an opportunity to enhance production values in a cost effective manner these filmmakers are setting the future trends in the film production process.

Looking into the future, the digital film revolution will run and run by providing new methodologies, which will continue to turn the conventions upside down. Just as new software will streamline today's digital production pipelines, so the industry at large will have to come to terms not only with the offer presented by digital photography but also with establishing a modus operandi for digital distribution, exhibition and the future proofing of digital film assets.

Like the television industry over the last 20 years, the film industry is finally embracing the digital world and in a few years time will wonder what all the fuss was about.

The Quantel Guide to DI offers an excellent starting point for those wishing to know more about DI, both from business and creative points of view. It also gives valuable practical information about the DI process itself based on real-world experience. I recommend it to anyone who is – or is thinking of getting – involved in the rapidly growing world of DI.

David Jeffers

*Managing Director, The Moving Picture Company Ltd*

*August 2003*

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## Introduction

This guide is based on the real-world needs and experiences of Digital Intermediate in action in the digital film industry. It describes what DI is, what it involves and what it offers, as well as raising some of the current areas of discussion and looking at the choices available.

The guide goes on to describe a realistic approach to the business and technology behind a commercially viable DI environment based on the Quantel iQ DI platform (Chapter 6 onwards). It is designed to be of practical use to those in, and those involved with, the industry. As such it does not seek technical absolutes but describes solutions and workflows that have been proven to work well in the real world of digital film production.

Steve Shaw, working as a consultant for Quantel, provided much of the material in this guide, which can only be a snapshot of a rapidly evolving subject. Steve maintains a comprehensive and up to date technical guide to DI on his website, check it out at www.digitalpraxis.net.


## Credits

Thanks to the many people who contributed to this guide, especially to our DI customers who are doing much to educate filmmakers about the benefits of the DI approach.

Particular thanks go to:

Steve Shaw
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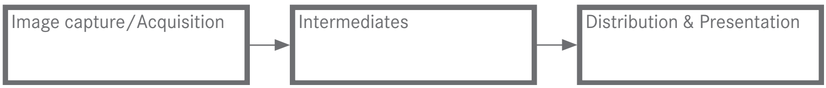
Digital Pictures

# Chapter 1: An Introduction to DI

## DI and Digital Film

In the film world, the term Intermediate describes a process that is one of the three major parts of the film scene-to-screen operation. The other two parts are image capture and presentation, the latter including distribution, projection and / or transmission. The intermediate stage accepts the shot material and produces the deliverables of the finished ‘film’.




Traditionally the intermediate stage has been performed by the film lab, cutting and splicing negative, adding optical effects and printing to produce distribution copies. Recent advances in digital technology now allow the intermediate stage to be handled digitally – a digital lab producing a digital intermediate (DI).

DI is a growing business and the process has already been used for over 300 movies with budgets ranging from the modest to the blockbuster. A few of the better known examples include:

| Film | Director |
|---|---|
| Amelie | Jean-Pierre Jeunet |
| Bad Boys 2 | Michael Bay |
| Bloody Sunday | Paul Greengrass |
| Bulletproof Monk | Paul Hunter |
| Fear Dot Com | William Malone |
| Hart’s War | Gregory Hoblit |
| Jim Brown: All American | Spike Lee |
| Lord of The Rings | Peter Jackson |
| O Brother, Where Art Thou? | Joel Coen |
| Panic Room | David Fincher |
| Pinocchio | Roberto Benigni |
| Pleasantville | Gary Ross |
| The Pianist | Roman Polanski |
| The Magdalene Sisters | Peter Mullan |
| Traffic | Steven Soderbergh |
| Dogville | Lars Von Trier |
| Ghosts of the Abyss | James Cameron |
| Star Wars Episode II | George Lucas |
| Saraband | Ingmar Bergman |
| Vidocq | Pitof |

The move toward DI as an alternative to the chemical intermediate lab, and more, is now well under way. This not just because it is a cleaner, quicker and more flexible alternative to the traditional approach but also because it is a far better fit for the modern media world. Films are rarely viewed only in the 'film' cinema; a few cinemas have already gone digital and many people see films at home via high quality DVD or digital broadcasting. DI creates an edited and graded digital master from which it is easy to make the highest quality of film copies as well as highest quality versions for all other media. At the same time well-designed DI can offer an easy and cost-effective path to create different versions and even trailers and promotions for the movie.

### DI Applications

- Feature film mastering
- Feature film restoration
- International versioning including subtitles
- Different release format versioning including D-Cinema, TV, DVD and HDTV
- Trailer post production
- High quality theatrical commercials (some use the DI process for SDTV commercials)

'Men with Brooms' trailer posted on iQ at Eyes Post, Toronto

## DI Benefits

DI is a replacement for the opto-chemical film lab environment. It offers digital negative cutting according to offline edit decisions. It also provides optical shot-to-shot transition processes, such as wipes and dissolves, and film grading to produce the equivalent of a timed interpositive (IP). This base-level operation is the heart of the DI lab but it's the enhancements that DI offers for everyone involved over the traditional lab process that are driving its uptake.

### DI for the Director

- Ability to see the entire project at an early stage
- Complete flexibility for change after the offline is finished
- Review changes instantly on a large screen
- Greatly improved colour enhancement tools without going through the VFX pipeline
- Simultaneous multiple versions including the 'Director's Cut'

### DI for the Producer

- Reduce the time taken for post production
- Reduce the costs associated with late changes
- Quickly produce multiple versions for audience testing
- Quickly produce all the different format deliverables

### DI for the Director of Photography

Retain compete control over the look and feel throughout post

Sophisticated colour enhancement available on every shot

Complete colour control over different format deliverables

High quality irrespective of the number of ‘opticals’

### DI for the Post Facility

A new service for its clients generating new revenue

High level creative work plus multiple deliverable production

Growth business

Infrastructure and expertise requirements limit competition

### DI for the Film Laboratory

Leverage existing relationships and expertise

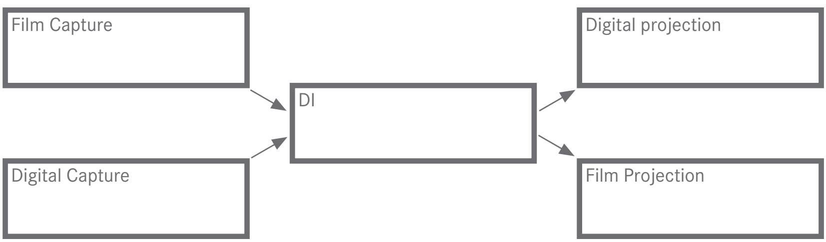
Develop current business by adding new services

Protect revenues by digitalising current services, e.g. HD Dailies

Position business for the increasingly digital future

All the above benefits apply however the original image was captured and irrespective of the final distribution formats. DI is not a process limited to digital acquisition or to D-cinema distribution. The capture, intermediate and distribution processes are totally independent of each other and that they can be undertaken quite separately in time and technology. This is important as it allows Digital Intermediate to be chosen for its benefits, not because of the use of any additional digital technology elsewhere in the project.

DI is useful however the image is captured and whatever the distribution format



## The Road to DI

DI has not suddenly appeared out of nowhere. The truth is that there has been a steady increase in the use of digital technology in film over a period of years that has led to DI, and during that time there has been much learnt by all those involved.

Today, digital media technology is in our hands every day. We can all pick up and use a DV camcorder and are happy to operate a DVD player. In both cases these involve highly complex digital technology that has been adapted and designed to offer controls and reliable operation that is easy to learn and use. The road to DI has involved similar processes and now offers similar ease-of-use and reliability.

Digital technology first came into many film markers' view in the late 1980s with the arrival of offline. A decade ago, film visual effects shots (VFX) started to be created digitally. This established a virtually lossless process for the film-to-digits-to-film path, the digital processes and power to produce good results in good time, as well as the storage technology to show live, full resolution digital film. As with offline, film makers have not looked back.

Digital VFX entailed working with only the few seconds of action involved in most VFX shots – albeit now used in ever-larger numbers per movie. Techniques like crowd replication, set dressing, digital pyrotechnics and shot fixing are commonplace. Once digital effects are used it makes sense to stay digital throughout the post process. Continuing development of key technologies such as disc storage and processing power has allowed the economic storage of entire movies. Other technologies such as digital film scanning – making a digital representation of the film – and digital film recording (back to film) have developed in parallel so that, today DI is a viable, cost-effective proposition as an alternative to the chemical film lab.

A significant part of the road to DI has involved establishing the exact requirements of everyone concerned and meeting these in a clear, easy-to-use and immediately understandable fashion so, for example, traditionally trained film timers can quickly apply their skills through the new technology.

## The DI Business

While the headlines talk about DI as a technology change, it would not hold up without a practical business model. Theoretically, DI has been possible for a decade or more and much pioneering work has been done, but the costs have been prohibitive. Now, DI and all its benefits are available at much the same cost as the traditional lab. As a result there are now many DI set-ups all around the world that provide good service to their customers and also make money. The pioneering days are over – DI is a proven business.

## About this Guide

The rest of this guide takes a look at the details of DI, the important choices to be made and concludes with a look at how the Quantel iQ fits into the DI process. The appendices contain some practical advice compiled from experience gained on many DI projects in USA, Europe and Asia.

**Chapter 2 The DI Process**

DI is a digital replacement for the optical film lab. Using the optical lab as a starting point this chapter outlines the fundamental requirements of the DI process.

**Chapter 3 Quality in DI**

Quality considerations are paramount when dealing with cinema sized images. This chapter concentrates on the different quality choices available and explains why 2K is the most common DI format.

**Chapter 4 Acquisition and Delivery**

Although DI as a process is independent from image capture and distribution it must interface to both. This chapter investigates developments in both fields and their impact on DI.

**Chapter 5 Building a DI Facility**

There are many ways of building a DI facility. This chapter outlines some of the key infrastructure and architecture choices.

**Chapter 6 iQ in DI**

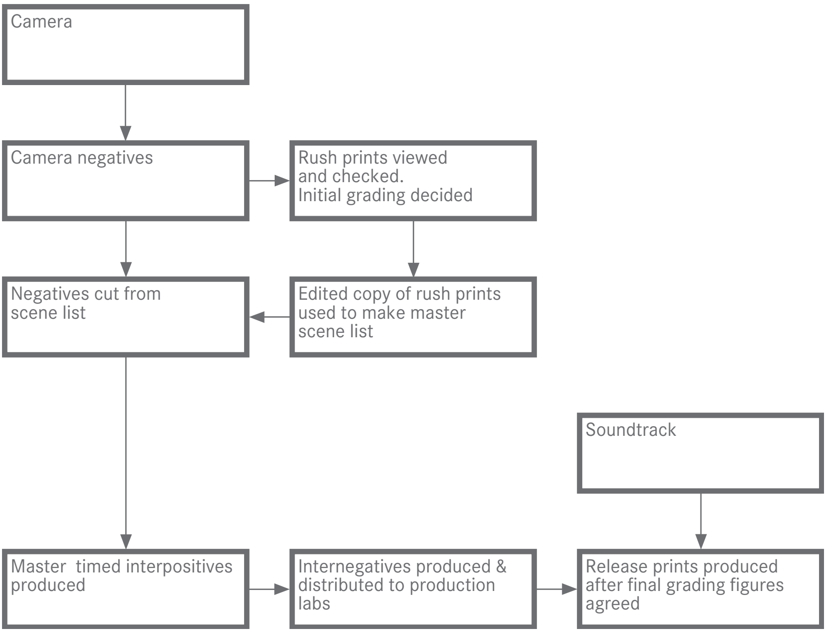
iQ has rapidly become the industry standard DI system, this chapter explains why.

# Chapter 2: The DI Process

## The Film Laboratory Process

DI realises a digital form of the chemical lab so must be able to produce a cut, timed intermediate for the production labs. Figure 2.1 shows a simplified workflow for a film laboratory.

**Figure 2.1: Traditional lab workflow**

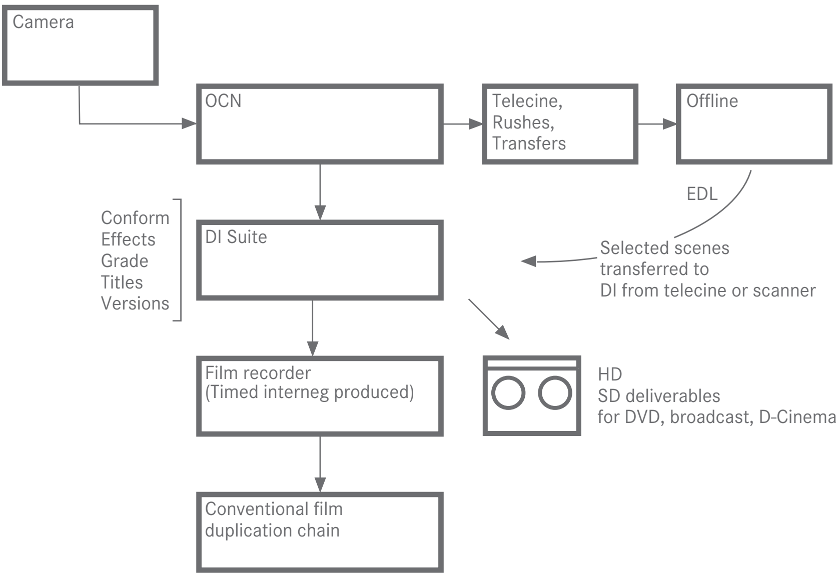



A film lab accepts original camera negative (OCN) and, after copying, editing, grading and optical effects etc. produces a number of internegatives from which the release prints are made. An interesting point is that copying (red arrows) incurs quality losses, so some detail of the OCN is lost. This point is covered in more detail in the next chapter.

## The Digital Laboratory Process

The key to realising a Digital Intermediate is to edit, grade and add VFX in the digital domain. This requires the negative to be scanned once, but thereafter no further manipulation of the negative is required. Figure 2.2 shows a typical DI workflow.

**Fig 2.2 A typical DI workflow**




## DI Essentials

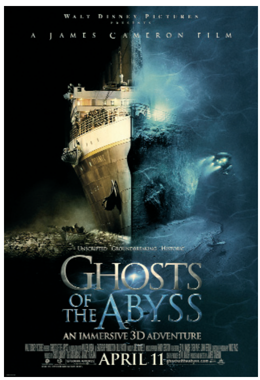
For DI to meet its aim of producing a timed, cut intermediate there are a number of basic parameters that it must meet.

Hold an entire film, complete with handles and variants, in full film quality.

Auto conform from an offline list.

Playback the entire film project in real-time, with temps / animatics / previews as necessary.

Display the film images in true film colorimetry, contrast, gamma, etc.




'Ghosts of the Abyss'. Finished on iQ at Modern VideoFilm

Respond immediately to changes for review and sign-off.

Perform basic functions necessary for DI including editing, opticals, colour correction, VFX, titles, etc.

Work with accepted technical image parameters to present a final image quality acceptable as ‘film’.

Several of these points are worthy of further consideration.

### Film Quality

Today, DI work is frequently carried out at 2K, i.e. an image size of 2048 x 1556 / 1536, with 10 bit log sampling of the individual RGB components. A full discussion of why 2K is often chosen can be found in Chapter 3 but it is generally accepted that it provides good quality and sufficient headroom for colour grading.

### Offline Lists

DI needs to accept a standard offline EDL or AAF file and conform the online material to it, regardless of where the online material comes from (film scanner, digital camera, telecine, etc) making frame-accurate edits for images and audio. Conforms can be controlled by timecode or by film edge code, either of which can work well. It is also possible for small inaccuracies to be introduced at various places in the film-offline-list-conform pipeline so there is a need to carefully check the conformed master against the offline dig cut.

Early in the DI process the conform may need to include temporary shots, previsualisations and even animatics until finished shots are available. Including these temporary shots gives a much better feel for the whole project early in the post process and allows some parallel working to reduce the time taken in post.

### Storage and Workflow

DI systems must hold the entire project, including active edits, work in progress, temps, etc, along with the low-resolution offline (Avid or Apple Final Cut) for reference. Specific shots will be transferred to dedicated VFX systems for complex and time-consuming work that is not cost-effective to execute in the DI ‘hub’. But this is a part of a controlled workflow – not one that is that is demanded by the restrictions of the systems in use.

At any given moment the client (DoP, Producer, Director, etc.) can review the whole project at full resolution in its latest form, interactively and on-demand with all associated handles and alternate versions available. To meet these requirements the DI system will require multiple Terabytes (1 TB = 1000GB) of storage as 2K data takes up over 1 TB per hour. With modern hard disks this does not present too much of a problem but access to and management of the storage remains an issue in some cases.

### Display

Images must be displayed in a controlled environment with the correct image colour temperature, colorimetry, contrast and gamma. The intent is to be able to confidently know that the image seen in the DI suite will accurately match the final deliverable, be it print, D-cinema or DVD. Sophisticated look up tables are required so that the DI images match the characteristics of print film and they need to be applied in realtime for DI to be a successful interactive experience.

Increasingly digital projectors are used within the DI environment for picture monitoring for two reasons. Firstly they can give a large screen experience which assists the creative process as the image is seen in its final form. Secondly digital projectors have a colour gamut that is far closer to a film print than any CRT based monitor. This is because they share the same wide spectrum white light film source as a film projector and control colour with optical filters that can be matched to print dyes. Their closer match to film makes accurately matching the display to a film print output that much easier.

### Input

Material needs to be accepted from any film scanner, telecine, or whatever source (such as HD tape) is required and generally this will involve recording very large quantities of data. As this may take some time, it should be controlled and executed without interrupting the other tasks of the DI lab. In addition, it would assist the quality goals if the material could be stored and used in its native format, so avoiding extra conversions which are liable to impact image quality.

### Calibration

As the DI suite is a 'WYSIWYG' (What you see is what you get) environment an important part of the DI process is calibration. Calibration encompasses the entire DI chain from input to output and ensures that the final output, whatever the media, matches the image seen in the suite.

Treating each part of the DI chain independently for calibration purposes allows scanning, processing and film recording to take place at different locations and ensures that errors in any part of the chain are not compensated for by more errors later in the chain. To make independent calibration a reality there needs to be a common tightly specified interface format. In the DI world that format is the Kodak developed Cineon file format, ratified by SMPTE in a somewhat modified form as DPX.

In reality the most difficult part of the process to control is the chemical lab processing at the end of the DI chain. Different organisations take different approaches here ranging from recalibrating only when there are film stock changes or when the lab changes the composition of the bath to checking the calibration several times per day. In all cases the calibration process involves outputting and printing test images, measuring the results and taking appropriate action. For more on calibration see Appendix 1.

# Chapter 3: Quality in DI

The technical quality of output from a DI lab is expected at least to match, or better, that of a chemical lab. This raises the question; what is the quality of film and how can it be expressed in digital terms? That then gives the key for matching or exceeding the chemical lab process.

The key parameters involved in digital quality are the spatial resolution, the dynamic range which breaks down into bit depth, log / lin scaling, the colorspace and compression. Another key aspect of DI quality is the conversion of film into digits where the two main types of device, telecines and film scanners, have different characteristics.

Although these issues continue to be debated the many films produced using the DI process are proof that DI can achieve high quality results.

## Why 2K?

The image resolution of 35mm original camera negative (OCN) is at least 3,000 pixels horizontally; some would say 4000, so why then is much DI work performed at 2K?

From the business perspective image size costs money. A 2K image requires about 12MBytes of data per 10-bit log RGB frame. A 4K image requires about 48MBytes of data, quadrupling storage and bandwidth requirements.

Successful films have also been made on digital formats of less than 2K resolution. George Lucas's Star Wars prequels were predominantly shot in high definition at 1920 x 1080. James Cameron shot the stunning IMAX 'Ghosts of the Abyss' on HD and even included some DV! These examples show what is possible. In most cases, quality owes a lot more to technique than technology.

So, the debate goes, just what is the correct resolution for DI? Up to 4K may be required for a true representation of the OCN, and therefore be desirable for a long-term archive but many feel it is not required for DI. DI works in a different way from the traditional lab as any copies it makes are perfect clones, there are no losses. It generates a final result from a single pass of the OCN, leaving the OCN in excellent condition so that it can be held for future generations, if necessary.

## The Business Approach

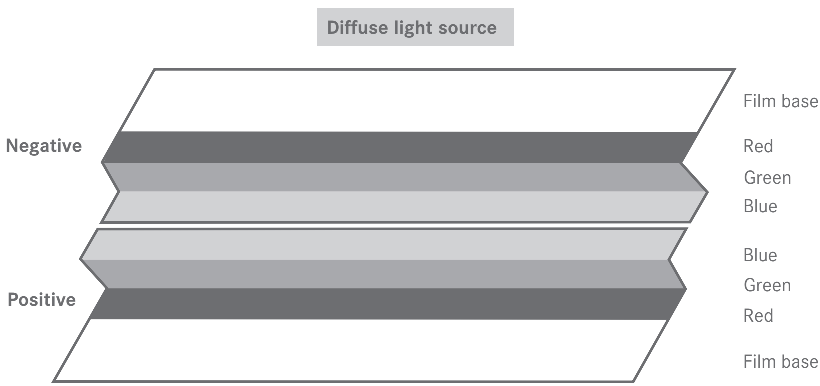
2K represents a good compromise for today's technology and business climate offering better quality deliverables than is generally possible today via typical film workflows together with costs that let every film maker take advantage of the benefits that DI can bring to film making.

But 2K is not a mandatory or universal solution; DI facilities need to be flexible enough to work in many different formats including HD and even standard definition video. As Jeffrey Katzenberg once said 'they call it show business not show art' and it is a rare DI operation that wants to turn down work because of a format issue. Filmmakers too benefit from the wide range of technology available today, perhaps allowing a location shot or special effect that could not have been afforded with traditional methods. (See Chapter 4 for more on different acquisition methods.) This chapter continues with a more detailed look at the parameters that go towards defining digital quality.

## Spatial Resolution

The traditional chemical process of generating a final film print by copying changes the spatial resolution of the images from that held on the OCN. Although the OCN resolution is up to 4K digital pixels, the resolution reduces every time it is copied – to interpositive, internegative and finally to print, where the resolution is closer to 1K pixels. This depends on the number of intermediate stages undergone and the quality of the processes used, but it is probably true for the average film process.

**Film contact printing is a source of resolution loss**




This is one reason why digital images of about 1K typically look at least as good, or even better than release print film. For example, while grading Pinocchio for digital projection and working at 1280 x 1024 resolution, the director and main actor, Roberto Benigni, was surprised to find his frown lines visible in the digital projected final when they were not in the film print. As a result these had to have their focus softened on the digital final!

DI does away with much of the need for multiple intermediates and, as they retain all image detail, the DI output can be considered qualitatively superior to chemically produced ones. Therefore, scanning the original negative for a 2K DI process will result in a final image of superior quality to the chemical equivalent, making 2K, or even less, acceptable for DI. However such numbers do not fully define the quality of the result. Better results are obtained from ‘over sampling’ the OCN: using greater-than-2K scans, say 4K. All the 4K information is then used to produce a down converted 2K image. The results are sharper and contain more detail than those of straight 2K scans. Same OCN, same picture size, but better-looking images.

Note: Scanning for visual effects work, which will later be inter-cut with the OCN, has different requirements. Realistically 2K is the minimum and often 3K or 4K is used as the digitally generated output negative will eventually go through the same dupe processes as the original negative.

Although 2K is generally considered suitable for DI, that does not preclude the use of higher resolutions where applicable. For example, larger images such as 4K are appropriate when using large matte painting background plates for panning and scanning a 2K window.

## Bit Depth

Bit depth concerns the continuous range of brightness that can be held by a digital medium – its dynamic range. Because of the way that film is used in its production chain, it is important to capture as wide a range of brightness as is likely to be needed from the original scene. It is this that is held on the original camera negative (OCN). The OCN is capable of recording detail both deep into shadows (blacks) and highlights (whites), as well as all the levels in between. As this wide dynamic range greatly exceeds that of the print stock – and so what we see at the cinema – it allows room, or latitude, for decisions on contrast, brightness and colour balance to be made during post production, or the film lab process, to ensure that the views are seen by the audience as required by the DoP.

The very wide latitude of the OCN is useful because, at no point during shooting can anyone be absolutely sure what exposure detail the film is actually recording. You cannot see the results until the film comes back from the lab. So the latitude gives room for any errors to be corrected during the intermediate processes in the lab – all a part of grading. As much DI work originates from camera negative, it makes sense for DI to handle a similar level of dynamic range. This can be achieved using 10-bit log data or 13-bit (or greater) linear data which gives a good level of granularity (brightness change per sample – see below) over the OCN contrast range. In some circumstances, 10-bit linear – or even less – may be acceptable due to the what-you-see-is-what-you-get (WYSIWYG) nature of DI where the results of grading adjustments may be seen immediately – so the operation becomes interactive and very accurate adjustments are possible – hence less latitude may become acceptable.

The final decision about bit depth depends on the approach taken to DI and at what point a timed digital internegative / positive is being produced. For flexibility and security this is usually the final stage (i.e., colour correction after all editing and VFX work has been completed) and requires a wide dynamic range to be available in the material. Many people agree on this while allowing for pragmatism and business requirements to shape the needs.

## Granularity

The more bits that are used to define the brightness (or values of red, blue and green) of a pixel the finer the 'granularity' and the smaller the brightness changes, steps or resolution that can be described. The more bits per pixel (bit depth) the finer the contrast detail that can be carried. For example, just one bit can convey full brightness and no brightness – black and white only, with nothing in between. You could say this is very high contrast, which it is, but there are no tones in between. Two bits can define four levels so this could add just two mid-tones as well as full and no brightness. Three bits can describe eight levels – and so on. In the natural world outside the digital domain, brightness is a continuous variable – there are no value steps, it is purely linear. The more bits that are used to describe brightness levels the closer we get to nature but there comes a limit to the number of steps that are needed – where if we had more, no one would notice the difference.

In practical terms to accurately represent the scene data captured on OCN requires at least 13 bits or 8192 levels. 10 bits or 1024 levels are enough when viewing images. See Appendix 7 for more on the bit depth required for DI work.

## Compression

Image compression is designed to reduce or remove what is considered as redundant information – the detail we are least likely to see – in order to lower the amount of data used. This is a good idea if the only use of the material is for direct viewing but in DI there will inevitably be multiple processes applied to the material (grading, visual effects etc.). As processing can only take place on uncompressed material, multiple decompress / recompress cycles are required, with a consequent reduction in quality if compressed images are used. It follows that compression is rarely, if ever, used in DI. However, it may well be used to record digitally shot material. In this case it is decompressed and recorded into DI. From there on the material should stay in first generation quality.

The image compression schemes used may produce good looking images but they may not be so good for visual effects work and grading – where the small amounts of visually 'redundant' information can be missed. This is especially true around edge detail and it causes 'noise' that becomes visible when processes such as blue- or green-screen keying, and selective or secondary colour correction are used.

However, for more basic story telling where post work is limited to grading and timing, a little compression need not be a problem. Often the benefits of lightweight electronic capture direct to an in-camera tape for dynamic story telling can outweigh the possible problems of compression. Creativity rules.

## Scanners and Telecines

There are two options for transforming film images into data for DI work.

- Film scanners
- Data-capable telecines

## Film Scanners

Film scanners have existed for some years and are very accurate devices for transferring film images into digits. They tend to be based on pin-registered transports, are very image-stable and capable of high resolutions. They are also relatively slow: typically taking several seconds for each film frame. This means they are not always ideal for DI use where entire films must be transferred cost-effectively and quickly. However, speeds are picking up. Film scanners are lower cost devices than telecines.

## Telecines

Modern telecines are capable of scanning up to 2K and even 4K resolutions. As they can transfer film frames in a fraction of a second, their use for DI input can be very appropriate.

However, some feel they are not without their problems. First, they do not use pin-registered gates and so are not as stable as the original camera. This is not of huge concern (they are far more stable than any film projector) and any instability is usually not visible – but can be a problem with visual effects shots. Here, tracking tools can provide a solution. Note that pin-registered gates are available but dramatically slow scanning speeds. Most would not consider 4K data scanning via a data telecine without pin registration.

Secondly, the use of a capstan, sprocket and edge guide for film stability can cause image distortion around film splices, especially where there is overlapped tape or badly registered splices. This requires long 'handles', of up to 3 foot, if the problem is to be avoided. For modern OCN stock this is usually less of an issue, as splices tend to be of the weld joined butt type.

The speed of transfer depends on the network connection (Ethernet, SAN or HSDL) and the transfer engine used (the device that translates the raw telecine data into Kodak Cineon density mapped log data – probably .DPX format but possibly .CIN). Transfer speeds at 2K can range from 4 to 15 frames per second. However, the faster the transfer speed the potentially lower the image quality – as the image sensors may not have sufficient time to accurately measure the film density, the result can be increased image noise.

The use of a sprocket to locate the vertical position of film can show problems during slower scans that are not evident during normal or real-time video scanning. This is because the sprocket is a loose fit in the film perforations, relying on its close contact with the trailing edge of the perforations to maintain the correct position. When shuttling back and forward the sprocket tends to swap ends of the perfs., taking up its normal trailing-edge position when scanning commences. However, when scanning runs at slower speed, film-to-roller friction can prevent the film taking this position after a fast rewind. The result can be vertical instability in the scan, which persists until the correct alignment is established. To prevent this affecting wanted frames, a longer-than-normal pre-roll is required.

With current technology, a good scanning speed for quality and throughput works out at approximately four frames per second, although testing of new film material is always recommended as the average density of any given project (the likely over or under exposing of scenes by a given DoP) will affect the light transference during scanning – and hence the quality for any given scanning speed.

## Film Scanners

Medium cost

Excellent quality

Highest resolution

Slow – seconds per frame

## Telecines

High cost

High quality

High resolution

Medium speed, 4-15 fps

# Chapter 4: Acquisition and Delivery

## Acquisition

Quality comes from the beginning and shooting on the highest quality format needed minimises any compromises. There is a debate today comparing Film and HD that is beyond the scope of this book to cover. For DI work the important point is that whatever creative or budget considerations have been made, DI should be able to get the right result. If for example a film shot production style demands grainy, less stable imagery to put across the emotion of the story then that consideration outweighs technical quality. But creativity aside, understanding some simple rules-of-thumb can help attain the best quality.

35mm camera negative has the highest resolution and latitude (dynamic range)

S16mm film costs less than 35mm but stores less information.

Film has the widest variety of available lenses

A large dynamic range is useful to maximise the potential headroom for grading. Film has the widest dynamic range, possibly 11 to 12 stops. The new-generation digital cameras have increasingly good ranges – of some 8 to 11 stops.

Full bandwidth RGB image information (4:4:4) generally has better performance than the half chroma bandwidth of YUV signals sampled at 4:2:2 especially when accurate keying / matting is needed.

HD cameras have impressive low light performance but greater depth of field than 35 mm film

When shooting HD be aware that compression introduces low-level artefacts which can sometimes cause problems in post.

HD cameras have no ‘weave’ or ‘hop’ which makes for very stable images.

Even when using standard ‘linear’ HD material or telecine’d data it can be useful to work with log scaled sampling.

There is no grain with digital acquisition

Today there is no high speed shooting beyond 60 fps with digital acquisition

There is no right or wrong answer as to which way to go – it depends on what you are trying to do.

‘Star Wars II: Attack of the Clones.’ Digital acquisition in action, Lucas Film, CA

## Digital Cinematography Cameras

There is now a range of new-breed digital cameras that have been made specifically to address the needs of digital cinematography. At the time of writing they include:

*Thomson: Viper FilmStream   www.thomsongrassvalley.com/products/cameras/viper/*
*Sony: HDCAM-SR (CineAlta) www.sonybiz.net/cinealta*

These are able to provide uncompressed or mildly compressed RGB outputs with a good dynamic range. Data can be presented in 10-bit lin or ideally log form similar to the industry standard .CIN or .DPX density mapped log files. This means there is good latitude to allow extensive re-grading during DI to maximise the creative possibilities.

CineAlta and Viper shoot Common Image Format images of 1920 x 1080 pixels and the Origin has an image sensor of 4046 x 2048 pixels which can be downconverted to suitable formats – such as 2K.

All the above currently offer fixed frame rates but another camera, Panasonic’s “Varicam” *www.panasonic.com/pbds)*, can capture images at from 4-60 fps so providing a degree of over-cranking and under-cranking. In this case the images are 1280 x 720 pixels, progressively scanned.

All these cameras show the way forward for digital image capture devices and further reduce the perceived quality differences between digital and film – while exhibiting many advantages. When combined with the benefits of DI and the possibilities of direct digital projection, is it possible that we will soon see major changes in acquisition.

## Conventional Digital Cameras

Although not made for cinematography, it is possible to use cameras built for HD television – and even SD television. HD cameras produce images that are up to near 2K in size (1920 x 1080) and have the advantage that they are probably more easily available and relatively lower in price. Their electronics are set up to suit the needs of television rather than film. In particular this means they are set to produce high contrast images with a contrast range of about only about five stops. They are also adjusted to take account of the characteristics of television tube displays and so apply gamma correction – bending the contrast response curve. With some careful setting-up of standard HD cameras it may be possible to enhance their dynamic range by changing the 'knee point' of their contrast curve. Clearly this is a highly technical issue so reference to the camera manufacturer will be needed to seek further information.

One strong argument in favour of the HD tape cameras is just how quickly and easily short films, student films and 'local content' specials for cinemas can be produced. A recent 'Digital Test Bed' event at the National Film Theatre in London included first time short films acquired on Varicam and HDCAM which were shot, posted and delivered in under a week!

## Recording Media

Today there is a choice of acquisition media for cinematographic shooting. Each has its advantages and disadvantages and the choice is made according to the artistic requirements of the project, the practicalities of the shoot and budgets.

### Film

35mm film predominates as the recording medium of choice for cinema projects. This is not purely due to the inertia of tradition but also to the qualities of the medium. Camera negative captures a very wide contrast range from the scene, holds the equivalent of 3K, some would say 4K, of image resolution and is a known quantity – giving a predictable look and feel. Super 16 costs less but has less resolution.

Compared to the digital alternatives film lacks the immediacy of seeing exactly what has been shot until the film comes back from the lab. Also, although the cameras are generally cheaper to hire, the cost of stock is higher, time and money must be spent processing and the cost of scanning into digits for DI adds to the overall bill.

### Tape

Tape has traditionally been the recording medium for digital cameras but the demands of the very high quality needed for film imposes special requirements. Nearly all the tape recording formats were developed originally for video applications and so make some compromises to reduce the amount of data that has to be laid onto the tape.

Nonetheless, tape compared to disk and film is a much lower cost recording medium with very high capacity. It is also easily removable, and not bulky. The smaller formats, DVCPRO and HDCAM, allow the use of inbuilt camera recorders, meaning that, with no external connections to the camera, it is free to move and roam.

Amid these television-based formats the introduction of a tape format made specifically for digital cinematography stands out. Sony's HDCAM-SR is designed for recording full 10-bit 1920 x 1080 images with 4:4:4 (or 4:2:2) sampling and uses relatively mild compression. At the time of writing this format is still in its honeymoon but its credentials are promising.

### Disks

Hard disks have the advantage of being able to record the very high data rates produced by digital cameras without having to compress the data. Portable recorders are available to record 1920 x 1080 10-bit RGB footage sampled at 4:4:4 in real time – nearly 200Mbytes / s at 24 fps. The disadvantages of disks include that as a medium, they are relatively costly, somewhat fragile and are bulky. So the data needs to be off-loaded as soon as possible. The hard disks used in such applications are separate from the camera, so there are cables and the associated restrictions in the use of the camera.

In some cases recordings are made directly to the disk store of the DI system creating a new pattern of workflow where DI operates interactively with the shoot. This can be especially advantageous for visual effects shoots where the matching of shots is vital for success. In the future it is likely that flash memory (as used in digital still cameras) will have a role to play as an acquisition medium.

## Delivery

In some ways the situation in delivery mimics acquisition with more options than ever before. On the delivery side though, unlike acquisition, one project often spans many different delivery choices.

In addition to conventional print and SD releases, films today may also be distributed on IMAX, HDTV, D-Cinema, Widescreen DVD, streaming files – all sometimes in multiple versions.

### Impact of acquisition and delivery technology on DI

The principle of DI is that it should be quite independent of the technologies used for image capture as well as those for distribution and viewing. It should be able to work for any type of input including DV, HD or scanned film, streamed files from the Internet etc. and to provide results which can be used in any required format on any media for any form of viewing, from PDAs to an IMAX experience.

The intermediate process has been a well defined area of the film production chain inputting OCN and outputting internegatives for the production labs to run off release prints. However, there are opportunities to offer a more efficient service in DI by the addition of appropriate features. These can help to streamline the transfer of material and make it easier to accept a range of media and to meet the individual needs of all targeted types of distribution and all viewing set-ups.

## Image Capture

Digital image capture has the advantage of directly producing digital images so there is no need to use a film scanner or telecine. Most material is still shot on film so that will be turned into digits and loaded into the DI system. What is important is that the DI system can accept the images, whatever their size, and efficiently produce an edited master that is up to the quality of that input. There are cases where material comes from several different sources and it is important that all these can be freely handled and edited together while maintaining the best technical quality.

## Delivery and Distribution

In the modern media world a feature film will not just be viewed on celluloid and in cinemas. Beyond the film output further processing is needed to produce various versions and formats and having the 'film' already available in high quality digital master form is a great bonus.

Rather than drawing the boundary of DI at the film-out or digital master stage, it can be beneficial to have some additional facilities available as part of the DI system to deliver a range of versions and masters for many, if not all, the required media and markets. Technically the work involves producing aspect ratio changes for 16:9 displays, pan-and-scan versions for 4:3 screens, changing image size to fit HD or SD television requirements and global grading adjustments to account for the different display characteristics of D-ILA and DLP technology digital projectors and domestic CRT displays. DVDs will require different cuts and more editing. As the DI system already has the material stored in the highest quality on disk, these additional operations can be very efficient and produce the highest quality.

# Chapter 5: Building a DI Facility

DI has only recently become commercially viable. Now the availability and cost of the required technologies have improved to the point where DI costs are close to those of chemical labs while offering many wider advantages for film production. There are several ways of configuring a DI facility. The exact configuration will depend on many factors including existing equipment on site, type of work undertaken, existing operational skills, required workflow, etc. All should be capable of producing excellent results but the time taken and the range of facilities on offer beyond the basics of DI may vary. To a significant degree, the choices centre on infrastructure and the equipment used.

## Infrastructure Choices

The main task of the infrastructure is to move the digital film images between the pieces of equipment that make up the DI system. As 2K image files predominate, the film sequences will comprise very large amounts of data – 288 MBytes for every second (24 film frames). If time is not an issue or only a few frames are transferred, relatively low speed technology such as 100 Mb / s Ethernet can be used but, for those requiring something closer to real-time transfers, high-speed technology is essential. In practice a DI facility may well use several types of technology applied to different areas as appropriate. The important consideration is that bottlenecks are avoided and an efficient workflow is achieved.

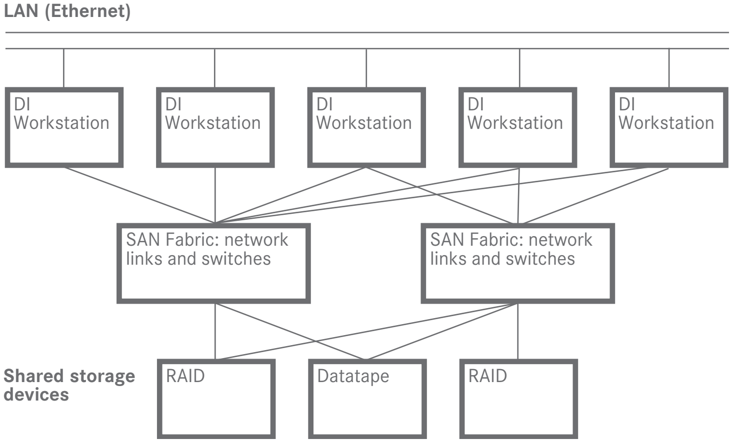
Whilst there are many choices for low-speed connections, the scope is more limited for high-speed infrastructure and these play a part in shaping the workflow of the DI system. Gigabit Ethernet, SAN and HSDL are some of the major choices discussed below.

### Gigabit Ethernet

Gigabit Ethernet runs at 1000 Mb / s and has the advantage of wide usage in the IT world and so is well developed and relatively low cost. Gigabit Ethernet can be used to build a LAN (local area network) capable of transferring up to six 2K images per second. As this is a networking technology achieving this performance depends not just on the network but also the ability of the sender and receiver to continuously handle data at that rate and the demands put on the network by other users. Some care in the choice of equipment and the layout of the network pays dividends.

### SAN

Storage Area Networks are a method of providing shared storage. SANs allow applications to have direct access to the files, cutting out the ‘middleman’ approach of the traditional client-server set up. This provides faster access to large files and more efficient shared working. Modern SAN file systems are cross platform so that applications using different operating systems (e.g. Windows, UNIX, etc) can share the same storage.




SAN design recognises that moving large amounts of data (film) is inconsistent with normal network general-data traffic requirements. Therefore they form a separate network to connect data-hungry workstations to a large, fast array of disks (RAID). Although any network technology could be used, Fibre Channel (FC) predominates. Its original 800 Mb / s data rate is currently widely used and allows 2K transfers at up to 8 fps. The rate has recently been doubled with newer technology so expect faster rates in the future. The direct connections to disks are ideal for making large, fast storage networks. In practice, both LAN and storage area networking are used side-by-side to offer wide scope for sharing and transferring material. Besides disks, essential items are FC switches and software for file sharing and management. Two SAN file systems in use in DI are ADIC StorNext FileSystem and SGI CXFS; both support cross platform data sharing.

Somewhere in between the LAN and SAN approaches outlined above is Network Attached Storage (NAS). NAS uses a LAN architecture but adds dedicated storage boxes onto the network. The dedicated boxes can outperform conventional server accessed storage and NAS is cheaper to implement than a SAN.

### HSDL

The High Speed Data Link provides an efficient transport mechanism for moving and sharing 2K film data between applications by the use of two HD-SDI links working together to make available nearly 3 Gb / s bandwidth. For 2K film this equates to a transfer rate of over 24 fps, although 15 fps is more typically used. As HDSL makes use of the HD-SDI cabling some facilities already have this infrastructure, so helping them to start up with 2K operations.

HDSL makes a useful connection to telecines. Note that this is not a networking connection where there is a two-way conversation to control the flow of data, here one end sends and the other has to receive. This type of continuous fast transfer is likely to occupy much of the power of any sending and receiving disk stores, so it has to be a foreground task: other operations must wait during this transfer.

### GSN

Gigabyte System Network (GSN) is an emerging networking technology that potentially delivers high network performance while maintaining compatibility with HiPPI, Ethernet and other standard networks. It can deliver 800 MB / s (6,400 Mb / s) with low latency for the most demanding applications and is suitable as a backbone for aggregating traffic from multiple gigabit-per-second networks.

GSN is a relatively new standard and is not, as yet, widely used. However, it is offered with some telecines. It is more costly than Gigabit Ethernet or Fibre channel.

## Equipment And Workflow Choices

There are many different combinations of equipment and capable of handling some or all of the DI application. The Quantel generationQ approach is the subject of Chapter 6. Some of the many other ways of setting up a DI operation are outlined below.

### Virtual Telecines

The first generation DI systems were servers and disk storage with front-end processing provided by a telecine, combined with hardware-based colour graders, such as those from da Vinci and Pandora. The workflow was disk-to-disk, with the image data passing through the hardware – including the colour corrector – as it moves. From the DI viewpoint, this is a hybrid – a linear approach using disk storage to reduce film handling and replays.

Until recently virtual telecines have had limited editing and no VFX capabilities so the work had to be passed on to other equipment. Also as virtual telecines, the systems were usually built around the assumption that all material arrives as film not as HD or SD.

### Repurposed VFX Systems

VFX compositing equipment can be used for DI. Here the workflow requires that the colour grading needs to be completed as shots are scanned and converted into digits. This is because the onward digital path may well have a dynamic range of 10 or even 8 bits linear, rather than at least the 13 bits linear (or 10 bit log) considered necessary for downstream correction. This can restrict further colour manipulation during or after editing, so narrowing future options.

In a sense the virtual telecine and repurposed VFX approaches are complementary. The former has strengths in scanning and colour grading and the latter in effects work.

Together there is the basis for an interesting DI environment. However, costs would tend to be high while throughput could be limited by the need to pass the very large amounts of image data between the system elements. In addition, one of the fundamental benefits of DI, its ability to retain flexibility for change at any point, could be compromised.

### Distributed Workflow Systems

Another solution comes from those that wholly embrace the ideas of distributed workflow for DI and is derived from a multi-workstation, computer-based background. These systems can be considered, in part, as 'virtual telecines' but they depend on using post facilities infrastructure to complete their work. This involves using separate systems for data I / O, editing, review and VFX work which depends on transferring large quantities of data between the various environments – tending to limit the speed of foreground operations.

The shots are spread across many, lower cost / power, platforms where specific VFX functions are carried out. Other platforms are used to review shots, usually in proxy (lower resolution) form and again more are used for editing and colour grading, and more still for background rendering at the final resolution. There is rarely a moment where all material can be found co-located in final and intermediate form, other than at the end of the project when the material is recorded back to film or to the digital master. This can make review of work in progress very difficult – especially seeing any given shot in context – and tends to reduce the flexibility for late changes.

Although movies have been made using this model, architectural limitations can require the use of proxies, giving rise to potential quality control issues. The need to move media between systems can create workflow and cost issues. Often the distributed workflow model is used on part but not all of the DI process.

# Chapter 6: iQ in DI

Quantel's approach to DI has evolved in collaboration with Post houses and Labs who needed a central piece of high performance equipment able to execute much of the operation and to efficiently support other activities and systems. The main DI product from Quantel is iQ which supplies many of the needed intermediate operations in an open, nonlinear form. This is a new approach that introduces the benefits of digital nonlinear operation to the world of film editing, grading – and more.

## About iQ

Figure 6.1 The iQ workstation offers pen-and-tablet control for most editing and DI functions, supported by separate controls for colour manipulation (QColor).

iQ is designed as the central 'hub' for a DI environment. Almost all DI work involves using a range of tools and systems from a range of vendors. With its own standard toolset designed for DI operations plus access to any third-party software development (applications and plug-ins) it offers the heart of a DI environment on one system. iQ is an open system and is designed to interface to third-party systems to create an efficient collaborative environment.

iQ is resolution co-existent so is able to work with multiple resolutions in a single project without rendering, has built-in VFX capabilities and is able to hold and play complete projects in full resolution, with edits that always remain uncommitted and open for change, as well as any variants or versions. With many DI sessions being client-attended, the interactivity of iQ is a real advantage, enabling DoPs, producers, editors and directors to be involved throughout the DI process.

## Capabilities

### Lab and More

iQ offers far more than a digital version of the chemical film lab's basic editing, grading, colour correction and optical transitions. Beyond these there are full nonlinear editing and secondary colour correction as well as VFX capability. This provides all that's needed to produce a final conformed and graded digital film, while there is always the flexibility to change anything at any time. The 'lab' process is available as an interactive operation where shots can be graded or cut in context – after they are edited into the film – to ensure exact, correct results.

### Versions, Formats and Deliverables

A film may well be required in many versions for different markets and media. iQ makes it straightforward to output any format be it film, TV, Quicktime or WM9. Resolution coexistence ensures the best technical quality as all versions can always be produced directly from the original data, not via some other 'system-native' or master format. Also there are needs for DVD masters requiring a simultaneous 'making-of' specials and generating necessary advertising trailers as well as foreign language, text and non-text versions, director's cut, etc. All these are produced with the correct colour gamut, resolution, aspect ratio, etc. to suit the each particular medium. In short, all deliverables are produced without needing to re-master, although care must always be taken when outputting for different presentation mediums, viewing conditions and formats.

### Flexibility, Accuracy and Creative Potential

Due to its technology, the chemical lab imposes some restrictions especially on the ability to change completed work. These no longer apply in the iQ DI lab. For example:

> The chemical lab requires that an optical cross-fade involves making a duped result. Once completed, any changes require the process to be repeated. Even this is not always possible, as negative cutting was probably needed to generate the first result.
>
> Offline dissolves are also becoming increasingly complex – such as three-layer cross fades – and are difficult to reproduce in chemical labs. Balancing colour between the two dissolve or fade shots is also difficult, requiring a compromise in colorimetry during the final grade.

In the iQ DI lab such edit transitions are simple and, even after completion, the separate in and out shots can be independently graded to ensure correct balance. In addition, the transition can be changed in any way, for instance moved, or given a different duration – all of which can be executed immediately. If the work requires obtaining any additional material, iQ does that automatically, even if a virtual 'neg-cut' had already been performed. More complex edit transitions can be treated in exactly the same way, with wipes and complex reveals being built, modified and graded exactly as for cut edits and cross dissolves, and undone just as easily, without needing to return to the original negative.

If the grading between scenes or sequences is out of balance, a re-grade is a simple real-time process. And, through the use of a film-colour calibrated grading monitor, scene colorimetry can be guaranteed, ensuring that the film output is as seen during the DI work.

As the whole project can be reviewed at any time – including temporary shots and the offline – there is the ability to modify in the context of the final edited film – the result is guaranteed.

### Scanning, input and networking

With a film shoot an offline EDL can be used to control the transfer of material into iQ as high resolution frames of data. The system understands and can cope with any 35mm or 16mm film format, including 3 and 2 perf., as well as any aspect ratio. Note that if for creative or technical reasons a production chooses an alternative format it is unlikely any serious problems will arise.

Film is typically scanned at 2K, 10-bit log, and transferred via a data network directly into iQ for immediate review and appraisal. The primary grading tools make it easy to be pre-balance shots to remove unwanted colour bias and so maximise the detail of images.

If using a networking architecture, input or output data transfers can be background tasks in iQ, with no impact on any foreground operation. However, if using HSDL, which streams data, it must be a foreground transfer which rules out other simultaneous foreground operations (See Chapter 5, Infrastructure Choices).

### Metadata and AAF

Besides image and audio channels iQ also includes a system for handling metadata. This is based on the AAF format and it serves to collect all such information on input, such as EDLs and any other information that may be supplied such as details of the shoot e.g. date, time, GPS, ownership, etc. Details of any work done to the images and audio in iQ are added to the AAF data as history, which has a number of benefits including:

Use of the history allows unpicking work so that any aspect may be later adjusted and the result re-assembled – for example, colour correcting footage three layers down in a multi-layered effect.

AAF is an open standard so the data is compatible with other AAF compliant equipment, and, if they have the appropriate tools, they can continue the work.

AAF can carry data on all aspects of editing and DI and it can be used as a ‘Super EDL’ to convey far more than cuts, wipes and dissolve decisions from offline to online.

Using AAF can create a very flexible editing archive with both material and all information about how it has been processed available.

When inputting material, source timecode in the headers of the DPX or CIN files (or embedded timecode within an HSDL stream), which is linked to the original film keycode, is transferred into iQ as AAF information. This enables frame-accurate EDL-controlled edits and the detail of subsequent changes to be stored. Use of the embedded film keycode is also a possibility although, as yet, not all components of the DI environment can use it.

If SD or HD video is the source, the scenes are transferred directly into iQ using a VTR control protocol complete with accurate timecode information and under the control of an EDL.

### Offline with Online

If an offline EDL is the basis for the film-resolution online, all selected takes are loaded into iQ complete with matching source timecode, and the edit is auto-conformed. If, for any reason, some source material is not yet available, iQ simply inserts a blank clip as a place holder, or can even use the low-resolution offline material, to ensure creative continuity until the correct clip is available.

This simultaneous use of offline with online, which is resolution co-existence in action, allows the offline material to be used as a digital cutting copy and played split-screened with the full resolution online material. This is a great benefit when matching complex edits to the offline, which helps ensure 100% frame accuracy at all times.

### Full Quality Online

Speed is vital for maintaining cost-effective operation and allowing time for creative input. Playing 2K digital film in real-time, regardless of the work state, mixed media position or total duration, means there is no need to work with lower-resolution proxy images. This ensures that every process, edit, grade and change is the real thing. There is no chance of later surprises when low-resolution previews are finally replaced by full-resolution data.

### Interactive Operation

With real-time 2K operation, the creative talent – DoP, Editor, Director, Producer – involved in the production can interact with the post production. This allows late decision making and instant action, when the unexpected happens.

### Grading

Colour is a vital component of image post production that surpasses all other forms of image manipulation when assessed as a percentage of all work. A work methodology has grown up based entirely around the requirements of colour – the telecine grading suite. This is a self-contained operation exclusively for colour manipulations prior to material being farmed out to edit suites and VFX systems for graphics, effects, editing and finishing.

Now such exclusive colour-based rooms are slowly giving way to alternative operations where colour manipulation is applied after all other processes, as the final step rather than the first. Here all shots can be seen in their final context along with the completed editing, graphics and VFX work. Such integrated colour manipulation provides a number of alternative approaches.

### iQ Colour Grading Options

Through close interfacing, DaVinci and Pandora colour control systems can be connected directly to iQ to provide virtual telecine grading via known and understood user interfaces. These can easily be driven by colourists who have experience and skills with the controls. The alternative is iQ's QColor integrated colour system comprising a dedicated control panel and internal colour grading software.

As a result there are two different approaches with broadly similar goals. What are the differences and why the two options?

### Third-party Colour Controllers

The use of iQ with da Vinci or Pandora grading systems provides a known and understood colour grading environment where iQ provides both source and record destinations for the material. The level of integration surpasses that of a normal tape-to-tape or disk-to-disk grading environment as it is possible to maintain all uncommitted edit decisions and extra edit handles throughout grading. As this is executed in the full dynamic range of 10-bit log image data, it is equivalent to grading direct from a negative – but without the possibility of negative damage due to repeated film shuttling and with the benefits of in-context viewing and instant access to all material – no spooling.

da Vinci and Pandora also provide power and tools through the use of additional dedicated hardware. This enables up to real-time secondary grading, power windows and blurs, etc., the speed depending on the resolution of the material being worked on. The fastest system in use today is the Freeflow link between Pandora and iQ which enables real time 2K grading.

The benefits of this approach include a known operational environment allowing operators to work as usual and on a familiar user interface, providing client-attended sessions with the expected immediacy and interaction.

'Mike Bassett: England Manager' – first feature to be graded on an iQ and Pandora combination. The Moving Picture Company, London.

## QColor

iQ's QColor provides broadly similar functionality via a dedicated control surface designed to integrate with the pen, tablet, keyboard and shuttle control of iQ.

Figure 6.2 QColor controls provide a familiar 'three balls' panel and jog / shuttle controls to access stored material.

The major difference between QColor and da Vinci / Pandora linked to iQ is that QColor uses the existing internal processing hardware in iQ for all its colour manipulations. While this contributes to its cost-effectiveness it can result in increased processing times for the more advanced complex grading demands. It offers controls for gain, gamma, printer lights and balance, in RGB and / or YCrCb colour space, primary and secondary grading, in all resolutions and formats. More advanced facilities include dynamic keyframe effects, selective window grading and multi-layer set-ups applied to enhance the result. If a project depends on colour to impart mood and feeling, this has all the creative flair and control needed while maintaining full flexibility.

However, as QColor is an integral part of iQ, there are no limitations on moving between grading, editing, effects, audio, text, paint, etc. It also means that, for the first time, it is possible to grade independent layers inside multiple layer key / composites VFX work so any image element can be accessed and graded at any time up to lockdown of the edited master. This grader inside an NLE system introduces a new way forward for colour management.

QColor's primary and secondary corrections include unlimited selective secondary colour with user-definable curves integrated with multipoint image tracking. This compares with the rectangles and ovals of traditional colour correctors but comes at the cost of some increase in rendering times. However, due to system structure, certain complex manipulations on QColor such as secondary correction have no impact on processing speed.

QColor should not be viewed as a replacement for da Vinci / Pandora but as an alternative approach for colour correction, especially considering the growing requirement for DI. This is a market where traditionally colour manipulation has been executed by film graders on grading benches, not colourists on video grading systems. Cost expectations are appreciably lower but the need still exists for accurate and powerful image colour control.

### The Choice

Both approaches are complementary. There are iQ owners who have opted for QColor because they view the toolset as sufficient and the cost model is beneficial. Others have chosen da Vinci / Pandora as their clients expect traditional colour manipulation. Yet others have both – the best of both worlds.

Traditional film labs have a wealth of skills at their disposal – including highly qualified colour timers. As the iQ DI lab uses film colour-balanced display monitors similar to a traditional timing bench, colour timers can direct the grading using skills already honed to perfection in the chemical lab. So a favourite lab colour timer can oversee the QColor grading.

For a grading environment that needs to be a clone of the more traditional telecine rooms the traditional industry-standard colour correctors from Pandora and da Vinci may be more appropriate. In this case iQ acts as a 'virtual datacine' – supplying the footage for grading and recording the result. In this way iQ DI provides all levels of colour control.

### Effects Tools

iQ's toolset is well advanced for digital intermediate film lab operations. Due to its Resolution Co-existence, it stores inputs in their native resolutions, and can freely mix any, up to 4K size, on an edit timeline. Internally, paint, DVE, colour, blur, editing, tracking, etc. tools are supplemented by third-party plug-ins to enhance system capabilities.

### Audio

With sound an integral part of the film experience it makes sense to have it available for the decision-making process. Sound can be imported into iQ either as a digital audio stream from a DAT or VTR, or as a digital audio file, such as WAV. Linking the audio and image information allows simultaneous playback and, with 8 channels available, 5.1 Surround Sound can be heard to enhance DI operation. And if changes are being made after the audio dub is complete, this is a good way to guarantee continuity.

### Output

Completed, signed-off work is typically output to a film recorder for the master output with SD and / or HD copies also being produced from the same 2K master material. The realtime SD, HD and 2K versions have specific output grades applied for the colour requirements of each version – directly from the 2K master. iQ can also supply WM9 / QuickTime outputs for web use or remote checking of work in progress.

For output to film the 2K master can be sent to a film recorder, such as an ArriLaser or Celco system, for outputting to intermediate 35mm film stock. The calibrated viewing conditions of iQ mean that the output, which may be the entire film, is a balanced and graded film master ready for the chemical duplication process. Here, the need for any further re-timing is greatly reduced – there may be none at all.

For digital cinema applications and TV broadcast use, as well as later DVD releases, HD and SD VTR copies of the same edited information can be simultaneously generated. These can be either with or without film colorimetry applied. For web marketing, WM9 and QuickTime clips can be generated from the same material, as can high-resolution stills. There is no need for a full re-grade for video copies, as would be the case with a film master produced through a traditional chemical lab. This ensures the video release really does match the cinema original, with no quality losses through the normally numerous film dubs and telecine transfers needed to generate the various format masters.

If the work has been completed in 10-bit log space and using iQ's calibrated log-to-print monitor display LUTs, a secondary colour control is needed for any video (HD or SD) outputs. Although it may seem to be a simple procedure to playout the 2K master final via the log-to-print LUTs with HD or SD selected as the destination, this is not the case. All work for film output uses viewing conditions best matched to cinema (very dark environment) while for video output, light needs to be reintroduced into the grading room – as for a normal telecine session. This drastically changes the on-screen perception of the image and requires a different grade style. It may need only a simple global grade, but will probably still require that some shots are lifted or have their contrast altered to preserve the feel of the 'film' original in the TV environment.

### DVD Pre-mastering

The same workflow can also be used for DVD pre-mastering, especially from classic film material. Based on a real working environment, the workflow involves scanning HD data files but at 4:3 aspect ratio (1440 x 1080 or 1920 x 1440 10-bit RGB) and not dropping to true 16:9 aspect ratio HD until the final output to tape. The clients then use this HD master to generate the DVDs locally, maintaining a quality impossible any other way.

### Near-line and Archive

Near-line networked RAID or system SAN storage (depending on the network specification used) is used for short-term archive backup of iQ jobs and for network transfers. After a job is finished, in case problems are found shortly after delivery, the archive data held on the network storage can be used to ensure alterations are completed quickly and without the need to reload from 'slow' tape archives. From this storage the DI lab can backup to tape (DTF2, LTO2, S-AIT, etc) for longer-term archive.

## iQ DI Lab – Ethernet-based System

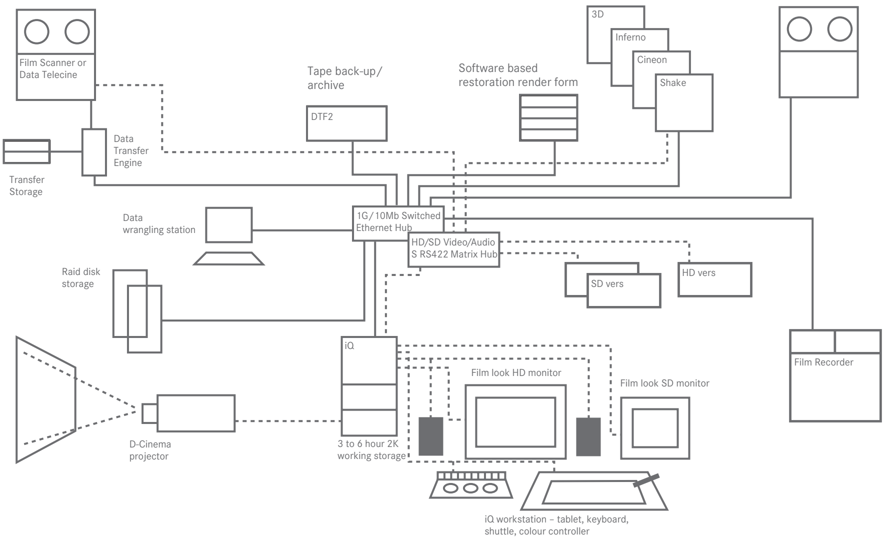



Figure 6.3 Example iQ Lab using an Ethernet network

### Technical Description

A 1G / 100 Mb Ethernet network makes use of iQ's ability to input and output data as a background task. This operates through a QXMLnet (see below) data wrangling station or QXMLnet-enabled third-party software application tool, with zero effect on iQ's operational performance. The result is a simple system approach that is aided by the fact that nothing slows down during the necessarily very large transfers of the data that make up the 'film'.

Files from the 2K film scans are transferred from the film scanner to local disks via the transfer engine. The scanner is usually set to scan at 4 fps, allowing overhead for simultaneous access to the disks for data file retrievals or saves by any other system on the network. 2K images can be transported over the network at around 6fps, depending on the destination and system bandwidth capability. This figure is based on an average Gigabit Ethernet network with network improvements providing additional speed increases.

### Workflow

The usual first step is for the iQ to start to load the material via the data manager QXMLnet data wrangling station (PC) as soon as it is ready. This is generally while a previous job is being finalised on iQ, meaning that time down time between sessions in minimised. If necessary, as soon as the first frame has transferred to iQ, work may begin, while the remaining frames continue to load.

### QXMLnet

QXMLNet is a set of utilities driven by command prompt to allow a remote PC to interrogate the clip bin of a generationQ system. This can push clips into the system in the background and take clips off the system – also as a background task. There is also a mode which allows for a remote system to rotoscope a clip, replacing the selected frames with the newly worked ones.

Being command line driven may seem old fashioned but it offers the ability to create batched transfers to load or unload clips. The commands can be readily incorporated into third-party software to integrate the process with external applications. Examples of this can be seen with Imagineer Systems' Mokey and Bright Systems' Data Wrangler.

Material is immediately assessed in real-time and full resolution on iQ and work often begins with some sections being transferred to 3D systems, or alternatively 2D tools, for simultaneous cost-effective processing. The material may be imported directly from the original scan data, from the local scanner disks or exported from iQ if preliminary work has been done there.

The local 'nearline' network attached RAID disks are used as a temporary storage way-point as, unlike iQ, most other systems in the DI lab cannot import and export data without affecting their primary foreground operation. The network disks act as a buffer so that system timescales can be met.

When any processing has been completed outside iQ, the resulting clips are either placed onto the network disks for QXMLnet to load them into iQ, or sent directly to iQ. There they can be inserted into the project and may include temporary (offline) shots to be replaced when the final ones are available. This often results in mixed formats and files such as AVI, SD, HD and 2K (any resolution / format) material mixed in one iQ project timeline. The whole project is always available for review regardless of the status of any given shot.

The monitors and digital projector driven from iQ can be fully colour calibrated via user-controlled LUTs (see Appendix 2) to match the final film or video output. This is to ensure the image being worked on is always correct for the final output format.

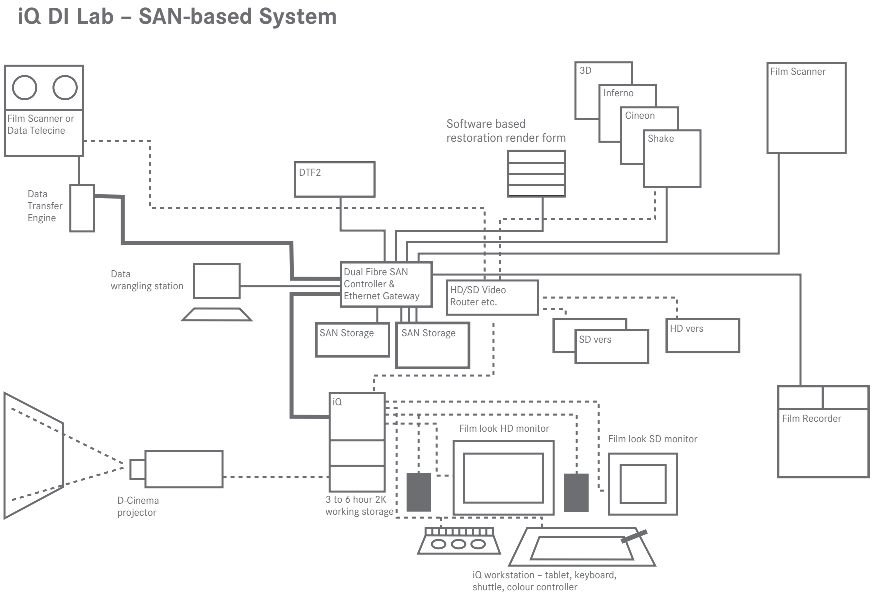



Figure 6.4 Using a SAN the workflow is similar but uses Dual Fibre Optic to link the main components. This can increase data transfer rate to double-digit frames per second (14fps for example).

# Appendix 1: Scene-to-Screen Calibration

One of the 'black arts' of digital film is considered to be calibration of the entire DI chain, from input to output. However, with a little logical thought this is actually a relatively simple process.

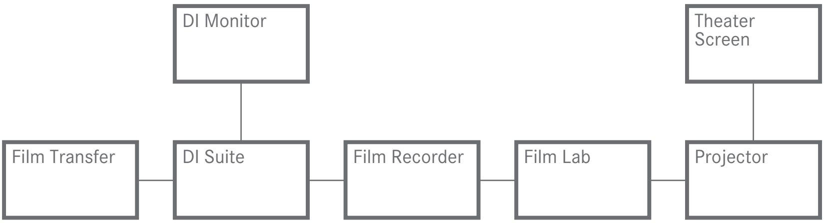



Fig A1.1 The DI chain

## Film-to-Film Calibration

What it is worth pointing out up-front is that the digital part of the DI chain is very easy to calibrate. It is the chemical lab processing at the end of the chain that is more difficult to control and as the digital grading process aims to match the final chemical print colourimetry you can already see the main difficulty in end to end calibration.

Each part of the DI process can best be considered in isolation as by maintaining calibration through each part it is possible to predict the effect of any change. This is especially important if film scanning, vfx & film recording are to be performed in separate locations. What is to be avoided at all costs is a calibration process where any error at an early stage is corrected at a later stage in the DI chain, or vice versa.

## File Format

Ignoring the few DI operations that have their own data format and are therefore isolated islands, all DI systems are [should be] based around the Kodak developed Cineon [.cin] file format, since ratified by SMPTE as the DPX [.dpx] format.

This format, in .cin form, is a 10bit log format that maps each digital sample to a equivalent negative film density of 0.002d per sample, giving a total density range of 1,024 samples X 0.002 density = 2.048 d-min to d-max, which is beyond the exposure range of most scenes captured on negative film. This results in the .cin format capturing a digital 'clone' of the original negative, including all shadow & highlight data.

The .dpx format differs only in that it can hold log or lin data, depending on its header flag setting [.cin is always log]. For DI work it is log we are interested in [although it is worth noting that as of writing this document most 'scanners' do not set the log flag for .dpx headers, requiring post scan setting through a computer script or similar]. Oh, and .dpx packs the image data within the file in the reverse to .cin!

With this choice of file format each stage in the DI process need only to adhere to the format specifications for full end-to-end calibration to be maintained.

## Scanner Calibration

All film scanners are either factory calibrated to the .cin / dpx format [Genesis, Imagica, NorthLight, etc.] or able to be set to match the format via some user intervention [DSX, Millennium, Spirit, etc.].

Note: if using a telecine based scanner [DSX, Millennium, Spirit, etc.] care is needed to ensure accurate calibration. However, the goal of any DI environment is to grade the film to gain a specific look, meaning that small calibration inaccuracies during scanning can be acceptable [see the Appendix 3 Film Scanning ].

## Workstation Calibration

The central DI workstation where editing, grading, vfx, etc. is to be performed can both be easier and more difficult to deal with.

Easier, as if performing no grading function the workstation must simply pass data through itself, with no change [ie. work as a transparent 'unity' device]. This is always a good first check for any system purporting to offer DI workstation capabilities – is it transparent? It's amazing how many workstations and grading systems are not transparent when set to default 'zero' settings.

Difficult, because once grading begins the workstation's viewing environment must display an image identical to the final projected film image. This is the hardest part of any DI system calibration procedure but is also where top-end DI environments separate themselves from the run of the mill. It is also closely associated with chemical lab calibration [and hence film recorder] as discussed in the following sections.

## Recorder Calibration

As with film scanners, film recorders [ArriLaser, Celco, etc.] are also factory calibrated to the .cin / .dpx format. However, this calibration is based on Kodak's perfect 'film lab' processing [as is scanner & workstation calibration] and therefore will only be as accurate as the film lab itself. The difference between scanner calibration and workstation monitor & recorder calibration is that grading occurs after scanning making the calibration less critical, while what is seen on the grading workstation is required to be accurately reproduced on the final film print.

From this we can see that the greatest variable within the DI process is the film lab, and the requirement to match the calibration of the workstation monitor and / or film recorder to the specific lab to be used for final film processing.

## Matching the Film Lab

As the film lab has the final say in the colourimetry of the output from the DI lab it is obviously the reference to which the digital image must be balanced. If the film lab is 100% calibrated to Kodak AIMs then calibrating the digital DI lab to .cin specifications will result in a 100% accurate DI process. Therefore, ideally the lab should be perfect, allowing the DI environment [scanner, workstation monitoring & recorder] to be calibrated throughout to default .cin specifications.

However, labs are very rarely 100% calibrated due to the nature of the film processing procedure. And what if the client requires film stock other than Kodak to be used? And additionally there are two lab processes that need to be accounted for – negative and positive process baths.

Because of these variables adjustment of either the workstation monitors or film recorder, or both, is often required to counter lab / film stock differences.

Ideally, the film recorder & negative film bath should be calibrated to output a perfect negative [internegative or interpositive] after processing. From this a positive print can be struck. The best method to calibrate the film recorder & negative film bath combination is to output via the recorder a 'sensiometric' film strip with a range of grey values throughout the full density range. Film labs are calibrated by Kodak using 21 step sensiometric strips, which is not really enough for accurate calibration. Therefore, generating a 128 step strip [a single grey frame output for every 8th digital sample] will provide more than enough accuracy for recorder calibration. The procedure is to output the strip, process the negative and then measure each step [frame] with a Status M densitometer. The read values should be compared to Kodak's .cin aims and the film recorder output luts adjusted to bring inaccuracies back into line. If this process is carried out multiple times per day excellent accuracy can be attained. As a minimum it should be done after a new negative stock is placed in the recorder [new batch number], different stock type [Kodak, Fuji, etc.] or when the lab changes the composition of the bath.

One of the benefits of calibrating the film recorder and negative processing bath to output 'perfect' negatives is that the workstation monitor can be calibrated to 'default perfection' by matching to perfect Status A reference print frames [ie. perfect .cin calibration]. This enables such a film recorder / negative bath duo to output any .cin / .dpx image and generate an almost perfect internegative, from which a near perfect print can be produced, assuming the workstation used to grade the material was accurately calibrated for .cin image files.

With the recorder & negative bath calibrated the final calibration process is the positive bath & workstation monitor. This can be performed either empirically or scientifically – but both methods require an on-aim print, ie. the most accurate print possible. This is described in detail within Appendix 2, Monitor and projector set up.

What is different about the print process bath is that it can be / is controlled via timers / graders adjusting printer lights. This allows some correction for bath inaccuracies so it is theoretically possible to ‘always’ gain an accurate Status A print from an accurate Status M negative. Also, unlike the negative bath / recorder calibration, print calibration requires ‘real images’ with colour and detail.

Once a perfect print is attained the monitor can be calibrated either by measuring values directly from the projected image [i.e. off the screen] and building a monitor lut from the data, or by comparing the projected image to the workstation image and modifying by eye. Which ever approach is used the workstation monitoring set-up must include user controllable luts [look up tables].

# Appendix 2: Monitor and Projector Set-up

Assuming final output is to be projected print film [rather than video or digital projection only], one of the most important operations that need to be performed within any digital film grading environment – and an iQ DI lab is no different – is the correct set-up of the primary grading monitor [or projector – see later].

## Monitor Choice

The choice of monitor is equally important. Although flat screen LCD, TFT, etc. monitors are improving in quality and dynamic range they still cannot compete with CRT monitors, making CRT the primary choice for a grading monitor. Users may prefer a flat screen as the workstation monitor, but even here their limited dynamic range means important shadow and highlight detail may be missed.

Although computer monitors are RGB input devices they are manufactured to lower quality levels than grade one broadcast monitors. While the fluctuation in phosphor colour monitor to monitor can be overcome as part of the calibration procedure a lack of set-up stability cannot. More importantly any monitor's ability to track black levels throughout varying dynamic range inputs is vitally important for grading work to maintain an accurate presentation of shadow detail. This is an area where high quality broadcast monitors cannot be bettered.

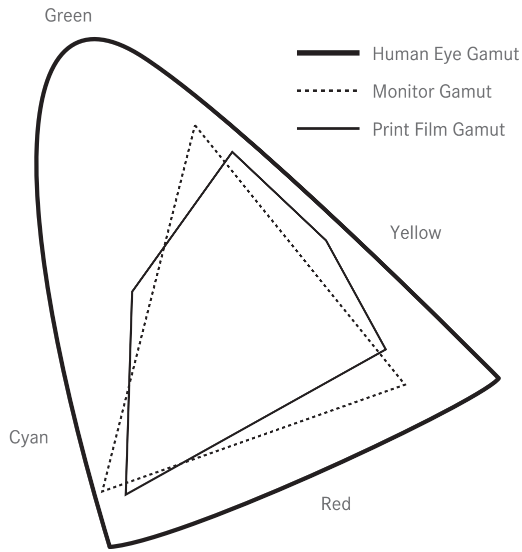
Therefore, for accurate colour calibration, stability and contrast tracking the best monitors to use are those that are the norm in any top-end telecine suite – grade one broadcast monitors. Do not be lead down the 'computer monitors are RGB and therefore better' path. You will live to regret that.

It is also important to understand that the colour gamut of a monitor [the ability of its phosphor to display a range of colours] is different from that of film and therefore there are colours that film can display that a monitor can't and colours a monitor can display that film cannot.

This is shown in the following [rough] chromaticity diagram.

For more accurate film matching during the digital grading process a quality digital projector is a better bet as its colour gamut can be matched more accurately to projected film [see later].

**Chromaticity gamuts**




## Preparation

It is important to understand what the intention is when setting up a monitor for digital film grading. Although a video device it must be approached with a film mindset.

The basic requirement is to ensure that what is seen on the monitor matches, as accurately as possible, what will later be seen as a projected film print.

This has a number of requirements before we get anywhere near the iQ output Lut calibration.

The use of known reference images in both digital & film print forms.

Access to a film projector.

A correct colour temperature light box [if possible with variable illumination capability – or a selection of ND filters to match the projector's light output].

Someone with 'good' eyes [i.e. a colourist].

A Grade One HD monitor [used in preference to computer monitors as it is a known quantity & of high quality].

Very dark viewing conditions with limited light contamination. [This is to match a film theatre's viewing conditions].

## The Procedure

### Reference Material

Using digital reference frames [Quantel can supply these but they must include a good grey scale, colour swatches, flesh tone & a LAD patch] output the raw data files to film via the usual [well calibrated] film recorder & process through the chosen [well calibrated again!] film lab & print.

Measure the Status M negative density of the LAD AIM patch to prove the accuracy of the film output device / neg. bath and Status A density of the print LAD patch, to prove print bath accuracy, and ensure they are accurate to Kodak specified tolerances. Nothing further can be done until an accurate print exists!

LAD Print AIM Density – 445 patch
(Kodak values – other film stock will have different aim values)

Status M - R-0.87, G-0.93, B-0.91
[5242 intermediate IP stock]

Status M - R-1.02, G-1.09, B-1.08
[5242 intermediate IN stock]

Status A - R-1.09, G-1.06, B-1.03
[vision & premier print stock]

## The Grading Environment

Careful consideration must be given to the illumination conditions within any room to be used for film grading. Normal telecine rooms use lighting conditions more appropriate for projects to be seen under general living condition in normal homes. Film projection occurs in more controlled environments within a theatre and the ambient illumination is many times darker than home viewing of TV. For this reason the film grading environment must be similar. Any light contamination will reduce the contrast range & shadow detail of the grading monitor resulting in inaccurate grades being performed. If in doubt shut out all light except for the usual green 'Emergency Exit' that is always to the lower left of any UK cinema screen, red if you're in the US!

## The Monitor

If you are using a CRT monitor for grading it needs to be a Grade One HD monitor for reasons outlined above & the Sony Multiformat series meets the requirements well.

The monitor should be set-up as per manufacturers instructions as a starting point, making sure this is performed accurately with careful attention to black detail with a Pluge test generator in a correctly set-up grading room as defined above.

From this set-up one input should be set to 5500K (D55) to better match film projector colour temperature, which is 5400K (-100 / +300), hence the use of 5500K for the monitor [note: one alternate monitor input will need to be kept to normal HD standard for video deliverable viewing].

As the standard monitor defaults are D65 & D95 this 'film calibration' needs to be set manually using the following coordinates.

**Colour Temp. Coordinates**

| Temp | X coordinate | Y coordinate |
|---|---|---|
| D50 | x0.3457 | y0.3585 |
| D55 | x0.3324 | y0.3474 |
| D65 | x0.3127 | y0.3290 |
| D95 | x0.2848 | y0.2932 |

This is done to enable the output from iQ to be colour balanced for 'film' viewing without the need to bias the iQ output [via the output Lut printer light controls] enabling an attached HD waveform monitor to correctly show grading levels. [If the iQ Lut printer light controls are used to set colour temperature the output RGB waveforms will be unbalanced].

## Contrast, Brightness & Chroma Match

With the correct colour temperature set the next step is to match black and white points via a projected or light box displayed printed grey scale & saturation via selected printed colour frames.

Standard film projector output levels are 16ft-lamberts for an open gate [no film in the gate], as measured at the screen. With base film [d-min] in the gate the output drops to 12 to 14ft-lamberts. Therefore the light box should be matched to 16ft-lamberts with no film present and the grading monitor to 12 to 14ft lamberts with digital peak white [1023].

Initially the iQ output Luts should be set to 'Log to Print' with all colour adjustments set to default. Select the digital log frame within iQ & turn on the output Lut.

With the same grey scale film frame on a previously checked light box [checked via a direct comparison with identical film in a projection theatre & matched to colour temperature & light output] the monitor output can be compared and brightness adjusted to set blacks & contrast to set whites. Note that if the previous 'video' default set-up has been performed correctly blacks [brightness] should need little adjustment. If you are making major changes go back and re-check the video Pluge signal alignment. White [contrast] can also be checked by measuring the ft-lamberts output when displaying a full white frame, as described above.

The contrast setting should also be checked with real images, such as Marcie, as grey scale ramps & steps can be difficult to gauge. Note that it is the main white point that is being set as contrast [gamma] is set via the iQ output Luts [see later].

Note also that if any ND filters are being used [see below] to limit the light output from the light box black detail may appear more crushed. This needs to be taken into account during monitor calibration.

Using a frame with good colour detail [macbeth is good] chroma can also be set to give a similar level of saturation, normally requiring the monitor output to be de-saturated from its default.

Average values are as follows, based on a previously accurate 'video' calibration of the monitor to set accurate defaults but also depends on print stock, processing lab and monitor size [the larger the monitor the lower its nominal contrast capability].

| **Nominal Monitor Settings** | |
|---|---|
| Brightness | 1000 |
| Contrast | 900 |
| Chroma | 830 |

Note that these values are based on the monitor having been previously calibrated correctly [using the Sony monitor probe BKM -14L & independently checked via a Minolta or Philips colour temperature & illumination probe] to nominal HD defaults with 1000 as the default control setting for contrast, brightness & chroma.

It will be necessary to use a selection of different frames and repeat the calibration procedure to gain the best overall result.

At this point the monitor set-up is complete and the monitor displays a Log image at 5500K with the correct contrast, black & white point and average colour saturation with iQ's output Lut set to 'Log to Print' with all other values set to default. What is probably still inaccurate is contrast roll off [gamma] and colour, specifically individual hue, saturation & luminance in R, G, B, C, M & Y.

## iQ Output LUT Set-up

With the monitor set-up as described above and with a selection of grey scale and colour Log images [macbeth, Marcie, etc.] the colour component of the iQ output Lut can be set.

Using a grey scale [a step wedge with a high number of steps is ideal] the lower Lut control for contrast [gamma] can be set first, making the peak roll off point consistent with print film. This can take some time to set accurately and using a selection of different images helps. It is important to get right, so take time and check and re-check.

When contrast is set accurately, colour can then be set as follows.

With a macbeth on the iQ output and the same image print on a light box start with the Green output Lut controls and adjust Green hue, saturation & luminance to match the image on the light box. Green hue must be adjusted first as it is a global adjustment and affects all colours. When set correctly move on to the other colour adjustments.

It will be necessary to check the adjustments against a selection of reference film frames and their original Log data to perfect the final set-up.

The most difficult colours to match will be heavily saturated colours [neon colours especially] as it is here that the colour display capabilities of film and crt monitors differ most widely. In truth, such colours can never be matched and a compromise must be accepted. Aim to accurately calibrate natural colours as these are most common & provide the most obvious indication of inaccurate calibration set-up.

## Starting Values

The following values should give a good general set-up for a Sony 32" Multiformat monitor correctly set as defined above to match Kodak vision print stock.

**LUT settings**

| | Hue | Sat | Lum |
|---|---|---|---|
| Cyan | 7.2 | 1.18 | 0.5 |
| Blue | -7.2 | 1.12 | 0.57 |
| Magenta | 6.4 | 1.1 | 0.82 |
| Red | 4.8 | 0.87 | 0.9 |
| Yellow | -9.6 | 1.36 | 1.21 |
| Green | 0 | 0.72 | 0.75 |
| | | Printer Lights | |
| | R | 0 | |
| | G | 0 | |
| | B | 0 | |
| | Contrast | 1.27 | |

Remember, these values are not definitive and the set-up must be checked as described.

## iQ Monitor Calibration Summary

Obtain a perfect 'Status A' print of calibration reference frames. These MUST be as accurate as possible. [Grey scale, LAD, Macbeth, Marcie, etc.]

If using light box calibrate to film projector standards using optical filters as necessary.
[Colour temp to 5400K & Illumination to 16ft / Lamberts]

Set grading room light levels to match film theatre. [Darker than telecine room!]

Calibrate monitor to default TV specifications as per monitor instructions & probe. [Check accurate black setup via 'pluge' signal]

Calibrate one monitor input to film projector colour temp & illumination levels. [Use probe to set colour temp to D54 (D55) & peak white illumination to 12 to 14ft / Lamberts – re-check black setup]

Display ref. grey scale image from iQ & turn on LUTs & set to 'log to print'.

Place 'perfect' Status A grey scale print frame on light box as reference.

Set 'contrast' control on iQ LUT page to provide correct contrast & white roll-off point on monitor image compared to print frame.

Display ref. macbeth image from iQ & place 'perfect' Status A macbeth print frame on light box as reference.

Set monitor 'chroma' control to match average colour saturation of ref. print frame.

Set 'G, Y, R, M, B, C' Hue, Sat & Lum controls on iQ LUT page to provide correct 'colour' on monitor image compared to print frame. [Set 'G Hue' first as this is a global control]

Check & compare black & white levels and adjust monitor 'brightness & contrast' controls as necessary. [Note: Adjustment of monitor 'brightness & contrast' should be minimal at this stage. Large change requirements show errors in earlier set-up stages]

Display ref. marcie image from iQ & place 'perfect' Status A marcie print frame on light box as reference.

Re-check settings.

Display ref. LAD image from iQ & place 'perfect' Status A LAD print frame on light box as reference.

Re-check settings.

Repeat last stages with various calibration reference images to verify monitor calibration.

Do Not adjust iQ LUT 'printer light' values!!!

MAKE SURE ALL FILM PRINTS ARE PRINTED ACCURATELY TO AIM.
[R.1.09, G1.06, B1.03]

Repeat calibration procedure on regular basis to maintain accurate calibration.

## Print Matching

The iQ Luts are also invaluable in matching the DI image to a final print, enabling the monitoring to take into account the inaccuracies of the processing lab.

Using the 445 LAD patch, Status A measurements can be used to define the printer light inaccuracies of the final print and the iQ Lut printer light controls used to offset the grading monitor image to match the print. Remember that the nominal iQ grading monitor set-up aims to represent a perfect 25 across print [although as the film recorder output will be to intermediate stock its 'salmon' base colour will require different light values – but you get the idea] but that processing labs vary rarely match this due to the nature of the chemical process film has to undergo.

A perfect (Kodak Vision stock) print with have the following 445 LAD Status A values:

R: 1.09, G: 1.06, B: 1.03

Therefore, if the Status A measurements show:

R: 1.08, G: 1.01, B: 0.97

The print will be [approx.] a point light and a point Cyan.

[Although Red is ok and is therefore not making the print Cyan, Green and Blue being roughly a point light appears to make the print Cyan & light].

As one printer light is equivalent to 0.07 density, to match the above print the iQ Lut printer lights should be set to:

R: -0.14, G: -0.71, B: -0.86

to provide an accurate match.

However, printer lights in the lab are not exclusive, with red affecting green & blue, etc. so as with everything to do with film it's all an approximation. Don't go chasing your tail!

## Using a Digital Projector

As mentioned previously, a digital projector can be far better colour gamut matched to the final film print image. This is because the light source is a wide spectrum white light, matching that of a film projector, and the RGB light paths are controlled via optical filters that are / can be matched the print film dyes. The use of digital lookup tables [LUTs] can further be used to match film's cross-colour contamination [the fact that within film there is no such thing as pure red, green or blue – or pure cyan, magenta or yellow for that matter].

As a result a digitally projected image can better match a final film result compared to any presently available monitor. Additionally, grading on the big screen has direct benifit as the image is being seen in it's final form – large – which also helps assess editing as on the small screen [tv] fast edits are a lot more acceptable than when viewed large. Grading via a digital projector helps bring editing and colour together for a better final result.

Note: Although a digital projector can better match the final 'film' image, as projected by traditional print film, that is not to say or suggest that film has a better or preferable colour gamut than a monitor or TV. Just that the two are different. If you refer to the chromaticity diagram previously you will see that neither colour gamut overlaps all of the other. In fact some of the more serious major digital film companies would like to see a projection film stock with a colour gamut matched to monitor phosphor. That would make all image formats immediately image compatible!

## Projector Calibration

The procedure to present a digital projector with a high quality image is similar to that outlined previously for monitors. The major difference is that theoretically for print film matched projections the basic colour gamut matching can be performed via the projector, probably using optical filters to match the film dyes. There has also been a lot of digital colour manipulation tables created for digital projectors with P7v2 being one of the more widely known.

Experience with iQ and digital projectors being matched to film projectors [DLP type digital projector from Barco & Christie, film projector from Kiniton] has shown that superb results can be obtained with minimal distortion to the iQ LUTS [10bit LOG images with close to default settings for the r,g,b,c,m,y cross colour values with contrast set to 1.3 as per monitor use]. In instances where the iQ output has been fed to a calibrated digital projector and compared to a film projector on the same screen the results have been awesome.

# Appendix 3: Film Scanning

After monitor set-up and calibration, scanning is the most important DI operation in determining the final quality. The following describes how this can be achieved when working with iQ.

## Quality Control

Although the iQ DI process will not further degrade images, it cannot improve on the quality of resolution and detail. Care taken in scanning will be rewarded by improved final quality, a general increase in ease of workflow and image manipulation ability.

## Scanning Requirements

Generally, frames input to DI will be changed in some way – in colour, contrast and possibly size and position. Unlike VFX shots, DI work will not be inter-cut with OCN. This reduces the need for perfection in scanning. Remember – this is a real-world approach. However, this does not mean only limited care is required. Any errors made which crop, crush, clip or otherwise lose information cannot be recovered later. All the necessary information must be scanned and available for the iQ DI Lab to do its best.

Therefore, the important parameters for scanning can be defined as follows:

**Geometry**

correct aspect ratio – circles not oval

correct image size – side to side correct

no image cropping – no missing image area

**Dynamic range**

blacks not crushed – black point correct

whites not clipped – white point correct

gamma nominal – grey point correct

**Resolution**

all image detail retained – no missed samples

image sharpness natural – electronic aperture correction minimal

if available, make 2K images from 4K scans and maintain MTF

If these parameters are maintained, the scanned data will contain all the necessary information from the OCN, enabling the iQ to manipulate colour and size without restriction – as if working directly from the negative.

## An Ideal Scan

For optimum set-up the scanned data should match the Kodak Cineon log density map for film density to digital data. This ensures a 'unity status' as most digital film systems, including iQ and film recorders, work with, and understand, film data mapped this way. Then the DI process is essentially invisible.

### Cineon .CIN/DPX Density Mapped data

D-Min to D-Max of 2.048
Mapped to 10 bit Log data:

| | |
|---|---|
| D-Min | = 95 |
| 2% black | = 180 |
| LAD | = 445 |
| 18% grey | = 470 |
| 90% white | = 685 |

Granularity of 0.002 density per sample (LSB)

The active image area, rather than the full frame, should be mapped to the available 2048 (or 4096 if using 4K oversampling) horizontal pixels. For example, if an Academy mask was used in shooting, only the Academy area should be mapped to the 2048 pixels, not the full frame aperture (resulting in only 1828 pixels per line for the academy area). This maximises the resolution transferred to data. Then, provided that the final 2048 image pixels are output to fill an Academy film area during film recording (see Appendix 5), the whole process is essentially set at unity – not introducing any distortions or changes, apart from those used in the grading or effects work.

## Film Scanning Procedure

For most DI applications, the latest-generation telecines are used at 2K and act as data scanners rather than traditional telecines. This requires set-up for log scanning based on the Kodak Cineon density data map, making the telecines clones of data scanners. In this way the DI film path adheres to a known standard throughout, as is required of a true intermediate process.

For most data scanners the use of Telecine Analysis Film (TAF) is an ideal initial set-up, looking to set 0% black (D-Min – frame bar black rather than scene black) to a digital value of 95, 90% white to 685 and LAD grey to 445 (or 18% grey to 470).

After TAF set-up, replace with the film to be transferred and re-check all settings. Accuracy here will ensure quality throughout the DI process. However, there is no reason to stick rigidly to these values as a small amount of 'pre-grading' can assist the DI post production, taking into account possible shot colour bias, lighting errors, etc. It is also important to correctly set masking for specific film stocks, enabling the data scanner to correctly understand the stock's cross-colour component and provide an as accurate as possible RGB separation.

If these suggestions are followed, the data used for iQ DI will deliver the best possible results.

# Appendix 4: Shooting HD

Many DI facilities with iQ offer grading of HD shot movies. iQ is well suited for HD shot DI material:

It can input and output HD RGB and HD YUV real time

It can handle YUV headroom correctly without RGB 'clipping'

It has specific tools for the vary-speed function on Panasonics 'Varicam'

It has specific tools for handling Viper Filmstream images

The use of HD digital cameras as the capture medium for 'film' projects is growing in popularity, not least because of their WYSIWYG operation where the results are instantly available on-set, the lighter equipment, lab-less shooting and potential for lower production costs. Recent figures from Sony show the combined cost of camera rental, stock, offline (including film processing, one light telecine and HD down conversion – where needed) and post are significantly less using CineAlta shoots against 35 and 16mm shoots – even with HDCAM post.

## Resolution

The resolution of an HD frame is also close to that of a 2K film frame (open gate film frame is represented by 2048 x 1556 / 1536, an academy frame 1828 x 1332 and a 1.85 frame 1828 x 988 while a 16:9 HD frame (a 1.778 frame) is 1920 x 1080. So, which is best for resolution?

The reality is that even though both can provide good results, direct digital capture can produce sharper results. The reason behind this is that shooting film and then then scanning is a two stage process whereas digital capture is a single stage process. The Modulation Transfer Function of each process multiplies together reducing the the high frequency content of the overall result. Oversampling when scanning the film image produces better results.

## Dynamic Range

However, most HD cameras are considered to have a perceived limitation exactly because of their WYSIWYG operation, namely that they do not capture any extended dynamic range (additional black or white information) beyond that normally seen by the audience. As already discussed, this lack of range means that, during post production, it is hard to greatly alter the image appearance (especially contrast) without blacks turning grey or whites looking flat.

## Extending Range

There are two approaches to improve the dynamic range of digital HD cameras. The first makes use of the camera's image sensor's (CCD) wider dynamic range. The camera is nominally set to provide immediately-useable 'TV-gamma' high-contrast linear images. But it is possible to adjust camera gamma to output a lower-contrast, but wider dynamic range, output. This output is obviously not immediately broadcast-useable but is a closer approximation to the capture methodology of film, and provides additional headroom for post-production grading / timing.

With this approach the likely extension in dynamic range is about 2-3 stops and can be applied to most, if not all, digital HD cameras (Refer to manufacturer information on the possibilities).

The second method, and possibly more interesting approach, is for the manufacturer to provide the camera output in a form more closely matched to film. The Viper, CineAlta HDCAM-SR and Origin cameras, already have such outputs. The Viper uses a CCD with a 12-bit front-end and this linear RGB data is immediately translated into 10-bit Log and output via HSDL to an uncompressed RGB diskc recorder. The available dynamic range is in the region of 8 to 9 stops – better than traditional linear HD cameras, but still lower than film negative. The Origin is nearer to 11 stops.

Note: It actually requires 13 bits of digital resolution to accurately represent a negative film's dynamic range of 2.048 with a 0.002 granularity, as specified by the Kodak / Cineon digital log file format.

It is worth remembering that the intent when shooting should be to capture an image that gives the maximum flexibility for post processing, not the best image for instant viewing. Capturing an image that gives post flexibility will lead to a better final result.

## Compression

Another characteristic of most HD cameras is that they record in 4:2:2 YUV compressed images onto tape. In their 'camcorder' mode, the level of compression is high. The alternative is to record on to a studio VTR deck with less compression to record 10-bit 4:2:2 data. Different HD camera systems use different levels of compression and bit depths. It is advisable to run quality evaluation checks under likely shooting conditions prior to any project.

Obviously the output from such cameras can be recorded directly to a disc recorder and so avoid any compression but, as with the use of a studio VTR, the camera will be tethered to the recording medium via a coax cable. Then this can reduce the benefit of using digital capture in the first place. At least a film camera always carries its recording medium with it and never uses compression...

Newer HD cameras and VTRs are also offering RGB 4:4:4 capture and reduced levels of compression, e.g. Sony's latest CineAlta F950 camera and HDCAM-SR tape deck.

## Depth of Field

HD cameras' image sensors are generally 2 / 3-inch across, smaller than a 35mm film frame. This results in a larger field of focus, depth of focus or depth of field, compared to an equivalent 35mm camera – but similar to Super 16. As focus is extensively used to help story telling by leading the eye to the point of interest, having a larger field of focus can detract from the perceived quality of the final image. So it is common to shoot HD with as wide an aperture as possible, using lens ND filters to 'stop down' the camera, maintaining as 'filmic' an image as possible. Using lower (wider) F or T stops also causes the focus to be slightly soft, giving a more filmic image. It also means there is increased danger of highlight blow-out. As already stated, take great care with scene lighting when using ND filters.

Due to the smaller-scale optics of HD cameras, back focus is proportionally more critical and needs checking after camera shipments to avoid detrimental effects. Collimators are available that can quickly check back focus.

Note: Exceptionally the Dalsa Origin camera has near-35mm sized image sensors, so the above field of focus difference does not apply and it can use the standard 35mm camera lenses.

## Image Framing

One of the additional benefits of a film cine camera is its use of an optical viewfinder. Most, if not all HD cameras use electronic viewfinders and, as a result, only show the image area they are actually capturing. It is therefore imperative that boom mics, and the like, are kept out of frame. It also means that the DoP cannot see 'around frame' and may miss the best possible camera framing for action as it enters frame.

## Rough Guide to Shooting HD

When shooting HD for a DI project there are a number of guide suggestions that will ensure the best end result. As with any image-based creative process, the quality of the initial capture defines the maximum final quality attainable. Care and time taken during capture will save time and cost in post production.

The following are rough guide points, not rules. They will result in an image suitable for DI manipulation on iQ and will generate an image that will be low contrast and 'grey' when viewed on / under normal HD monitor / conditions. It should be noted that, in following this guide, there will be an introduction of digital noise (video grain) if exposure levels drop too low. As with film capture, lighting plays a vital role both in quality of the final image and setting the correct creative mood and needs as much care as with film capture.

## HD capture guide

Check back focus!

Shoot 24P – maintain a 24 fps filmic image without interlace artefacts

Use 1 / 48 shutter speed to mimic nominal ‘filmic’ motion blur

Use ND filters rather than stopping down to maintain a filmic depth-of-field

Take care with scene lighting to avoid highlight blow-outs

Set camera for low contrast to extended the dynamic range capture and mimic film (see camera manufacturer’s instructions for set-up)

Avoid black crushing – mimic film toe characteristics

Avoid white clipping – mimic film shoulder characteristics

Aim to grade or time in post production not in the camera to retain flexibility

Watch scene framing – there is no safe area or over-scan area in an HD image

If followed, the result will be the most flexible use of HD capture for an iQ-based DI post.

# Appendix 5: Film Recording

Although a self-contained process outside iQ's control, knowledge of film recording, processing and printing is an important part of gaining the best from an iQ DI system.

## Data to Celluloid

As iQ expects digital film image data as Cineon density mapped information it can be viewed as a unity process, adding only its creative input to the image data and not corrupting it.

With monitoring set-up and calibrated as described in Appendix 2, any output will be matched to the industry .CIN / DPX log data standard – a known and understood entity. A well calibrated film recorder will, therefore, output a known 'digital film negative' matching the expected intermediate Status M density for a digital 445 LAD patch, as specified by Kodak, and assuming a well balanced and maintained film processing lab. An accurate print can be struck from this negative, matching the Status A density values for the LAD patch.

In essence, the DI film-out process aims to produce a neutral negative equivalent to a perfect OCN. As the film recorder will output to intermediate stock (5242) the actual printer lights used will be different from this, but the theory still holds true.

## The Process

Once all DI work has been completed, the digital film frames are sent to a film recorder, such as an ArriLaser or Celco CRT recorder. Each frame will be exposed in turn, building a new digitally mastered intermediate negative. Alternatively it may create an intermediate positive. Although this is less common it may have the benefit of reducing the number of dupe processes undergone towards striking the final print deliverable.

Note: As film recording is a relatively time-consuming and costly process, it is usually only used once per project and produces a timed and edited negative. Onward chemical dupes are then used to produce the interpositives and eventual prints. However, if the efficiency of the recorders could improve sufficiently, it may enable multiple internegative to be cost-effectively produced for the direct production of projection prints. When that happens, mass audiences will see a jump in image quality.

Speed of film recording varies according to film recorder make and model as well as data format and associated processing, such as sharpening. With a laser recorder expect 2-4 seconds per frame with 1 second per frame coming soon to a film recorder near you.

## Control of Recording

To guide film recording a selection of reference frames should be exposed at the head or tail of every output. These images should include the digital reference frames used to calibrate the iQ grading monitor (see Appendix 2) and any reference frames required by the film recorder. This may include a 21 step grey scale sensiometric strip, but as a minimum must include at least one 445 LAD to enable Status M measurement of the negative (intermediate) and Status A measurement of the print to be made.

# Appendix 6: Lab and Printer Lights

A basic understanding of lab and printer lights will help in obtaining good results when outputting to film. OCN records a scene as density in the film stock's emulsion. After processing, this results in the areas of the film that were exposed to bright scene information being dense (more opaque) and areas exposed to dark detail being less dense (more translucent). The film records the inverse of the original colour. Hence, the initial film recording of the image is a negative copy of the original scene. This is also true of the internegative produced at the output from the DI process. The positive image seen on the grading monitor is recorded (usually!) as a negative image on film.

When this negative film is copied (duped) light is shone through it onto new , unexposed, film stock. This stock is similar to the OCN as it records brightness and colour information in the same way, but as it is 'seeing' a negative image from the OCN , it records a positive representation of the original scene.

Making a projection print from a negative (OCN or dupe) follows the same procedure.

Note: The job of intermediate stock it simply to make a copy and not to alter the look of the OCN. So it has a longer 'linear' (less toe and shoulder region) response, smaller grain structure (it is a very slow stock as a lot of light can be used in the dupe process), and has a gamma of 1 so that it distorts as little as possible the characteristic of the OCN. For a better understanding of the film chemical process review the Quantel Digital Fact Book Edition 11 – film section (download at www.quantel.com).

The level of exposure seen by the new film stock is controlled by varying the amount of red, green and blue light shone through the original processed negative. This 'timing' uses values, called 'printer lights', to define the amount of light used. This timing process can be used when making a dupe (intermediate positive or negative) or when making a final projection print.

For a correctly exposed OCN, printer light values of R25 G25 B25 produce a balanced and mid-level exposed print, often described as 25 across.

## Printer Light Effects

As printer lights are used to expose a dupe film copy or print, they can control the relative density of the new film by varying the amount of light that is made available. For example, increasing the amount of the source printer light (which supplies the R, G and B lights) will make the copy denser overall – darker to look at assuming a print (positive) is being made but effectively lighter if a negative is being copied from a positive dupe.

## Printer Lights and DI

For DI work we tend to assume the new digital negative output from the film recorder is a fixed entity as little can be done to alter it, other than re-outputting the material again and re-processing – assuming this is a well calibrated film recorder. Therefore, when discussing printer lights in the DI world it is usually in the context of striking a projection print from the output digital film negative – the first answer print and proof of the DI process.

Obviously DI and the processing lab are striving to produce a perfect final print so that the film, when projected, perfectly matches the image(s) seen on the iQ grading monitor. However, as it is a chemical process, the lab cannot realistically be expected to attain perfection and it is usual to expect a variance of + / - 1 printer light per colour per lab process. This may not sound much but one printer light is a difference that can be easily seen, especially when a print is reviewed immediately after viewing the ‘perfect’ DI image on the iQ grading monitor.

Therefore the print’s Status A densities must be checked prior to any screening and an assessment made of the colour / brightness variation to be expected. If the variation is great, a new print should be requested, with the printer light values adjusted to counter the error.

Additionally, if the error is slight – within acceptable tolerances – the Status A density measurements can be used to alter iQ’s output printer light display LUTs for the grading monitor to mimic the print error. This allows the DI data to be reviewed as a match to the print, with the same error introduced. This is a very powerful and accurate way to prove the DI process allowing for the lab variations.

LAD print AIM density – 445 patch
(Kodak values – other film stock will have different aim values)

Status M - R-0.87, G-0.93, B-0.91
(5242 intermediate IP stock)

Status M - R-1.02, G-1.09, B-1.08
(5242 intermediate IN stock)

Status A - R-1.09, G-1.06, B-1.03
(vision print stock)

## Printer Lights and Density

Roughly, one printer light is equal to 0.07 density as measured by a densitometer (Status A) (7 printer lights equal about one stop). Therefore, if the Status A density reading of the 445 LAD patch is out by 0.07 the lab can adjust a reprint by one point (one printer light) to correct it.

It also means that the iQ LUT printer point controls can be adjusted to match the grading monitor to the print, balancing to the actual print values, rather than simply working with the ideal (perfect print) values used during the digital grading process.

Clearly, if all printer lights are out by an equal value the overall colour balance will be maintained – the image will simply be lighter or darker. If one or two printer lights are out, or all lights are out in different directions, the print will have a colour bias as well as being potentially brighter or darker. This is explained in the following table. It shows that increasing the printer lights will make the print more dense and more cyan, magenta or yellow. Decreasing the lights will make the print lighter and more red, green or blue.

**Printer light effect on positive print**

| Printer Light | -ve | 0 | +ve |
|---|---|---|---|
| | Red | 25 | Cyan |
| Colour | Green | 25 | Magenta |
| | Blue | 25 | Yellow |
| Density | Lighter | Nominal | Darker |

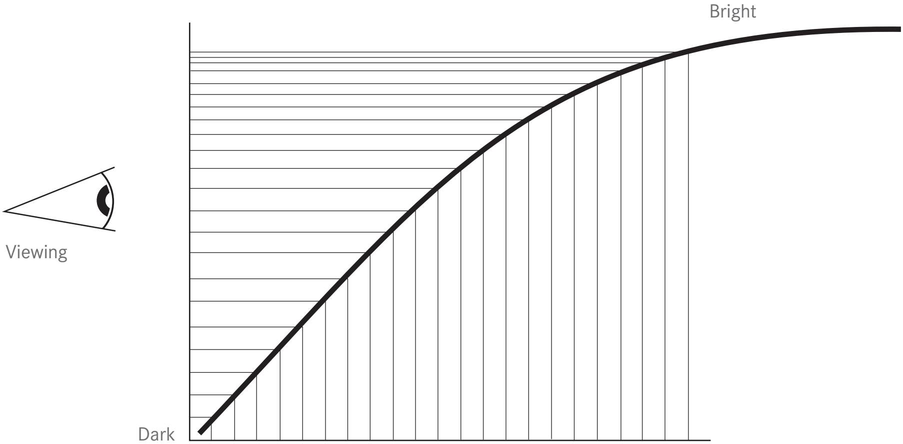
Therefore, if the Status A measurement showed red nominal, green and blue both less dense, the print will be cyan and brighter than expected. Note that the print will also appear less saturated and lower in contrast as a direct result of being brighter. This is more a trick of the eye than a physical reality.

Printer lights are also not direct-acting controls – adjusting red for example will also affect, to a lesser extent, green and blue. Using printer lights is definitely more of an art than a science but understanding the basics will be of great help in gauging what to expect from the iQ DI process.

# Appendix 7: Logarithmic and linear scaling

There is continuing debate about whether to use logarithmic or linearly scaled sampling. However, the real issue is, what dynamic range to use. The matter of the best method to hold that image digitally (log or lin) is secondary.

**Figure A7.1: How the eye perceives linearly scaled sampling**




Linear digital samples – with enough in shadow detail there are too many in the highlights

OCN holds detail from deep shadows into the highlights – a greater range than the human eye can see at one time. Film records brightness logarithmically, which is also the way our eyes respond. This means a small change in brightness in the shadows may be clearly recorded but that the same level of change in bright areas hardly registers. Imagine being in a dark room and someone across the other side strikes a match. It will be immediately apparent. However, if the room is flooded with sunlight the event will be all but invisible.

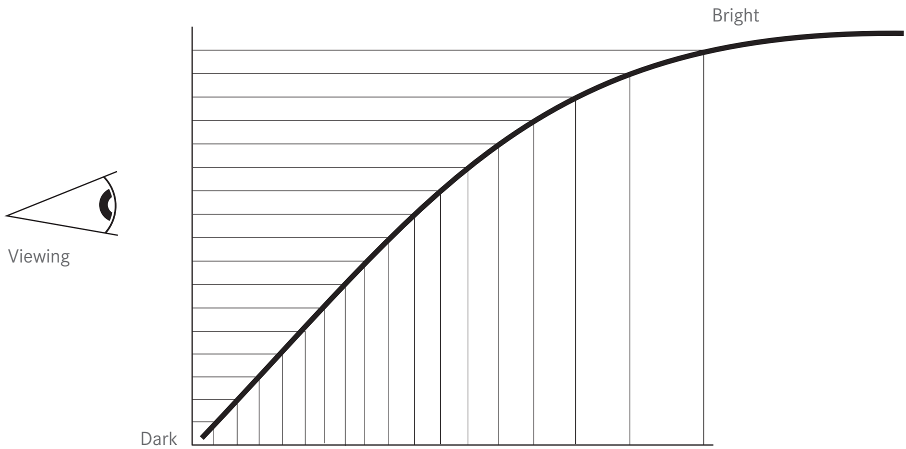
Electronic light transducers have a linear response. The Charge Coupled Devices (CCDs) that turn image information into digital data, output analogue voltage as a linear response to brightness, which is converted into a digital signal to produce linear digital data.

As small changes in shadow detail are easy to see, the brightness change per digital level, granularity, only needs to be very small to be noticeable. Using linear data, the same number of levels per brightness change will also be used in highlight areas, but here they may not be noticeable. They may be redundant as the perceived changes in brightness will be too small to see.

Another way of looking at this is to consider the actual linear digits. If the background brightness is at level 20 and some detail changed this to 30, this is a 50 percent increase and should be visible. However, if the background is at 1000, the same absolute value of change to 1010 is only one percent, and may well not be seen. Our perception, and film's, works on percentage change rather than absolute values. Percentage changes are similar to logs as both directly indicate ratios; absolutes are akin to linear data.

If the dynamic range being digitised is not large this is not too much of a problem, which is what happens with digital cameras when 4 to 5 stops of illumination information is captured. With 10-bit data defining 1,024 distinct values, or levels, there are enough to represent shadow detail accurately and not too many are wasted in highlight areas.

**Figure A7.2 Logarithmically scaled sampling**




Log digital samples – an even spread through exposure range

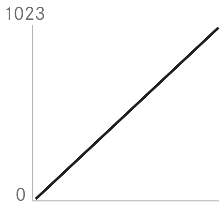
If the dynamic range is the same as OCN film's 10-to-11 stops, it will require 13-bit linear data providing 8,192 (213) distinct levels to resolve the information over the same dynamic range. But with equal linear sampling detail over the whole range of a non-linear response both 'bunching' and 'gapping' occurs – for example much is wasted the in highlights Raising the bits from 10 to 13 also increases the storage, processing and bus connection requirements by at least 30 percent. It has been argued that the 13-bit linear solution is wasteful.

If the whole large dynamic range of image information is converted into digital log data (like percentage changes), the distribution of the sampling levels is more efficient. There will be plenty of useful levels distributed in the shadows and enough in the highlights. In this way 10-bit log data can faithfully represent the full 11 stops of brightness that can be recorded on OCN. It can be viewed as a form of lossless compression and is the ideal data format for digital film DI work.

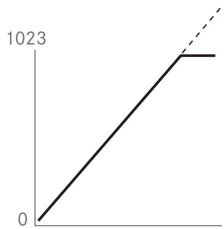
This is the basis for the Kodak-specified CIN digital film file format where each digital sample represents 0.002 density of an OCN (which is a log representation of the scene brightness), which is below the threshold of human perception.

# Appendix 8: Headroom – Log or Lin Recording

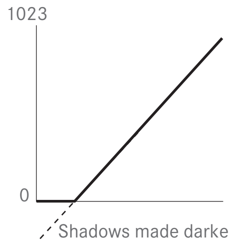
The benefit of log data holding extended brightness range information is discussed in Appendix 7. If image capture is on film or via a 'log' data camera, all is well. But even if a linear HD camera is used, this does not force 'linear' operation all down the production chain. It can still be beneficial to use iQ set for log data as this provides additional headroom which is useful during grading. Linear capture devices, television cameras and telecines not set to 'log mode', capture scenes or images and assign specific digital values to black and white. Using the ITU 709 or SMPTE 274M standards for HD television, in a 10-bit system (defining $2^{10}$ – 1024 discrete levels) black is set at 64 and white at 940. Although there is a small amount of digital room may be allowed above and below these levels, it is likely that such detail will be clipped. However, with careful control, this clipping can be minimised on all but the widest dynamic range images and generally video is shot to maintain good contrast by filling the available range – from black to white. So, with all the available data samples used up in holding the initial image, any grading performed in the same linear space will cause clipping, as the image is pushed higher or lower.



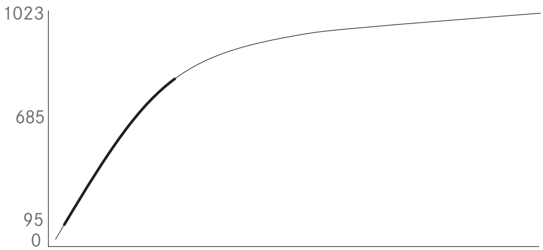
Original



Highlights increased causing clipping



Shadows made darker causing crushing



Linear data mapped to Log space giving improved head and foot room for grading without further clipping or crushing

However, if the linear data is mapped into log space the black gets set to 95 and the white to 685, providing very significant head and foot room for grading. Besides simply moving these points, the translation to log colour space means that the new granularity of sample (brightness change per digital sample) has effectively improved throughout the range too. The result is much better graded images.

Even if not going back to film, the use of print 'D-log E' -style log to lin conversion LUTs can maintain more of the new headroom than normal simple log to lin conversions where 95 is again assigned to black and 685 to white.

# Appendix 9: Workflows for Cut & Uncut Negative

There are many ways to operate within an iQ DI lab which allows it to adapt to meet the needs of individual projects. One area where there may be differences in approach is the use of cut or uncut OCN. The following shows how workflow in an iQ DI set-up could be organised.

### Uncut Negative

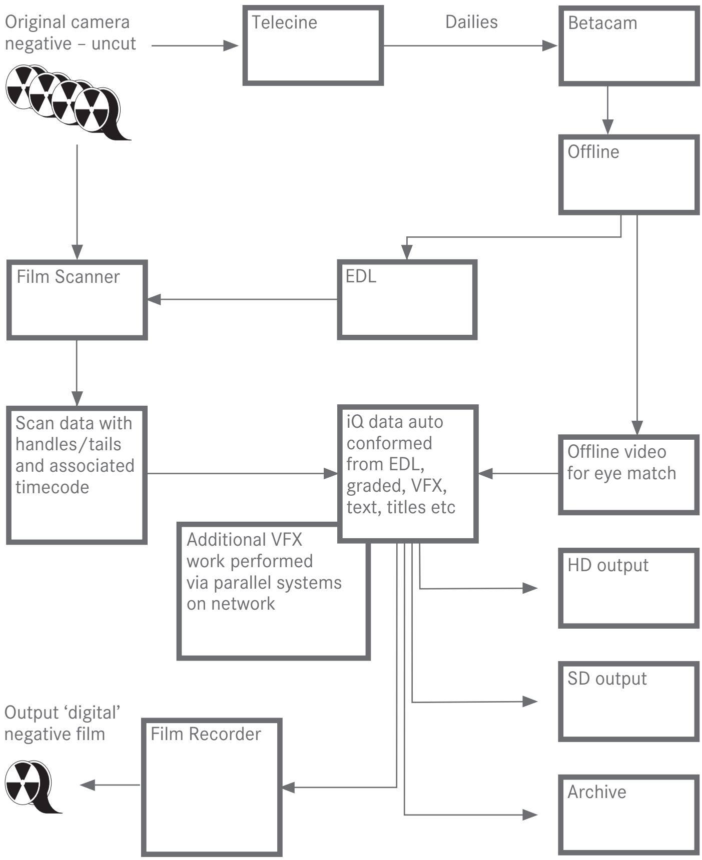



**Figure A8.1: Workflow using uncut negative**

Figure A8.1 shows an approach to DI workflow using film-sourced material where the original camera negative is never cut. There are a number of alternative workflows for this.

The OCN is telecined as dailies video transfers, usually from 2000-foot reels of spliced camera rolls. Each roll is hole-punched to mark the start frame, and the video transfer uses a timecode start of 1:00 hour, 2 hours, etc. for each reel. The transfer is frame-to-frame: the telecine runs at 25fps for 'PAL' (i.e. where the offline video is at 25fps / 50 fields / s) output to ensure one unique film frame is transferred to each video frame. For 'NTSC' (i.e. where the offline video runs at 30fps / 60 fields / s), the telecine runs at 24fps with 3:2 pulldown applied to generate 60 fields / s video. However, working at 60 fields / s in the offline will cause problems later as the offline video copy will not be suitable for use as a split screen reference to the online – it's better to offline on a 24fps capable system. The offline uses the video transfer to generate an EDL and low-resolution video cutting copy.

The takes defined in the EDL are scanned at 2K from the original uncut camera rolls. This enables the EDL to directly relate to the 2K scan requirements, making the online scanning easy to complete and conform. It also means the OCN is not cut, minimising the chance of damage and dust pickup. The downside is that the selected takes must be extracted from the complete rolls – taking longer at the film scanning stage. However, as scanning can start before a full edit lockdown, less time and money is spent neg. cutting and the likelihood of film damage is reduced.

## Workflow: Cut negative

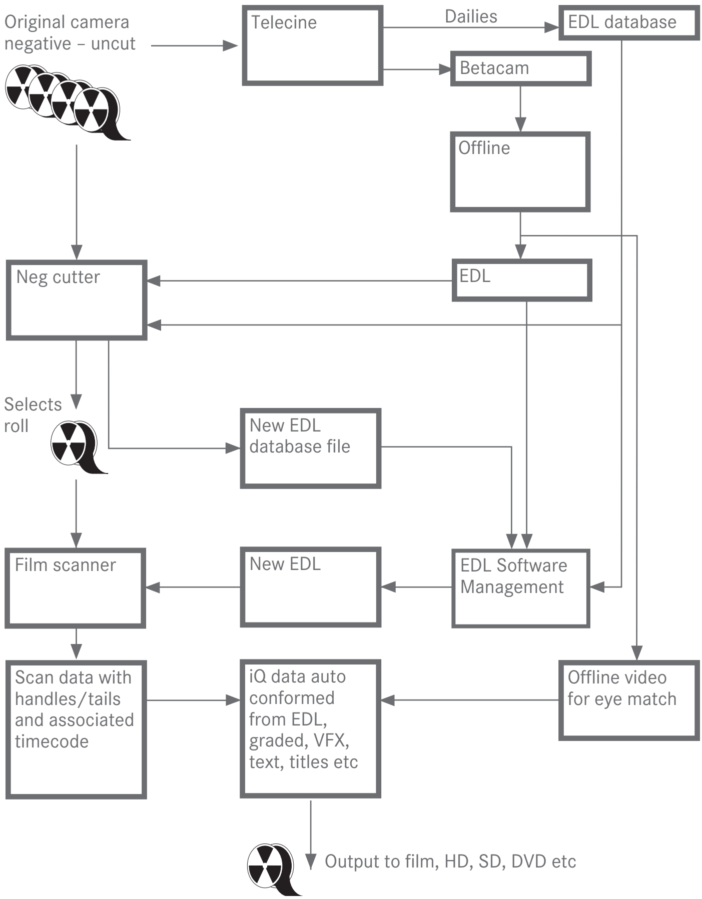



**Figure A8.2: Workflow using cut negative selects roll**

The alternative is to produce a negative 'pull list' from the EDL keycode information and neg-cut the OCN into selects rolls. These can be the selected scenes from the EDL, with handles or the whole selected take, flash to flash (clapper board to clapper board). This has the benefit of reducing the amount of physical film storage needed – but does mean that the negative has been handled more, although, with enough handles duration, this should not cause a problem.

Note that it is usually cheaper to neg-cut just the scenes to include handles, rather than flash-to-flash, but this can cause the image to jump during transfers if not using a pin-registered gate. Although the splice is in the 'handles' frames, it causes the length of the film run to alter as it moves over the scanner's rollers and capstan – so pulling on the frames being scanned in the gate and causing image distortion. To avoid this requires handles of about three feet.

Producing a selects roll also means the original EDL no longer references the source material correctly. The original EDLs from the offline will be converted by the neg cutter to represent the selects roll and thus will not affect the procedures described here. It must be updated to reflect the new location of the scenes and should be done as part of the neg. cut otherwise someone has to manually track and translate the keycodes back to timecode!

Although there is more 2K transfer work involved in film lacing and shuttling the original un-cut neg. rolls, there is a lot to recommend that approach. Whatever the method used, when all the material is loaded into iQ, the EDL is converted (by iQ) from CMX 3600 form to AAF and the whole project is auto-conformed.

# Appendix 10: Offline, Online, Timecode and Film

There is a lot of confusion on the present offline / online process for film DI applications due to the differing frame rates of video and film. However, it is not as difficult as it first appears and is described in the following that develops an original document by Thomas Urbye of The Moving Picture Company.

Neg. rolls will usually be telecined each day by a local post-house or the film lab as dailies, ostensibly to ensure the film contains the expected images and no re-shoots are required. Best to know this before moving location or striking a set and it is easier to view a video rush than a film rush, although film prints are often also struck at this stage.

Each reel will be approx. 20mins duration, and will be made up of a number of spliced camera rolls. A hole is normally punched in the reel as a reference point, usually nominal frame one, for the following video transfer and is placed exactly on the ‘hour’ of the Beta tape that the reel is being telecined to, with each roll using a different hour as roll reference [as much as that is possible]. From there the keycode reader will keep a sync of what timecode frame = what keycode frame and this data is held within the keycode reader’s database [a .fLEX file].

Because SD video has to work at 25 [PAL] or 29.97 fps [NTSC], the telecine for PAL transfers has to run at a speed increase of 4.1% thus achieving a frame for frame transfer and insert 3:2 to make up the missing frames from film’s 24 to NTSC’s 29.97.

For PAL it’s important to realise that running the telecine at 25fps makes one 24fps film frame equal one 25fps video frame with the result that the video version will run faster [have a shorter duration] than the film version but will have exactly the same number of frames.

You could run the telecine at 24fps to have a video version that runs the same duration as the film original, but the video version would have extra fields inserted to make the 25fps video output run for the same duration as the 24fps film original. No frames would match!

The important thing to note is that actual fps [timecode] is irrelevant with the timecode only being a way to reference each single frame. The beta tape, which is purely a transfer medium to get material into the Avid, will have a log floppy disk supplied with it [.fLEX file] that will contain the keycode / timecode sync relationship [the database]. This means that once the log file is loaded into the Avid it can maintain the timecode / keycode relationship internally [keeping them in phase] which will benefit the lab etc.

## PAL Offline

An Avid film composer gives you two options when working PAL offline [from a 25fps ‘frame to frame’ transfer]. You can either edit at 24 or 25fps. Creatively speaking, editing at 24fps matches the playout frame rate at the cinema [obviously!] but playout to a monitor happens via the insertion of an extra field every 12 frames to make 25fps for playout [SD monitors can't playback 24fps]. Working at 25fps means no fields have to be inserted but the project 'runs fast' and audio sync can become an issue as it is likely it was recorded on set at 24fps and will require a 4.1% speed increase.

Working with 25fps means that when the finished cut is laid back down to SD tape from the Avid the transfer is frame to frame, whereas if the project was done 24fps the Avid will insert a extra field on every 12 frames [so that a layout to tape is still possible and total 'duration' matches that of the film rolls, but frames don't match]. This has the nasty side effect of producing a 'judder' on tape.

Therefore, working in a PAL environment at 25fps [with Avid's 24fps playout option on purely for the editing / creative stage] is advisable, as this will allow sync with original audio and editing at the native film speed with frame-to-frame layout for offline / online comparison within iQ.

## NTSC Offline

For NTSC offline 24fps editing is fine as the offline will playout for monitoring at 29.97 [NTSC] SD with 3:2 inserted. Just remember to playout to tape a frame-to-frame version for iQ offline / online comparison.

## Telecine Data Transfers

As described above, there are 2 methods for data transfer for the online – uncut & cut neg.

Uncut neg. is very straight forward as it is just a high resolution version of the previous offline transfer. Each roll and its punch hole must be matched up and set to its hour timecode [01:00:00:00 for roll one, 02:00:00:00 for roll 2, etc.] and as you transfer, the keycode reader will take the selected shots it needs from your edl using the telecine's pull list option and transfer them as 2K data [having previously set the data telecine to 2K operation].

However, it is often the case that original camera negative [OCN] is cut into 'selects' with a couple of feet of film for 'handles', or cut 'flash to flash'. This has the benefit of reducing the amount of physical film storage needed – but does mean that the negative has been handled more, although with enough handles duration this shouldn't cause a problem.

The original edls from the Avid will be converted by the neg cutter to represent the new selects roll and thus will not affect the procedures described here.

Regardless of the method used, cut or uncut neg., as each frame is scanned, the timecode from the edl will be added to the header information for that .dpx frame, the frame rate will be irrelevant [although the actual scan speed will usually be 4 to 6 fps] as the timecode is purely acting as a frame reference marker. These .dpx frames can be loaded into the iQ via the network and conformed from the original edl, then played out at what ever frame rate you so wish from the iQ. The offline tape can be played alongside in real-time thanks to iQ's ability to play SD and 2K simultaneously so that the operator can confirm that the conform has been frame accurate.

Note: It possible to playout at 23.98, 24, 25, or 29.97on a film composer [from frame-to-frame transferred material] & this helps to match the film audio, depending on its frame rate, to your Avid timeline and for playout to tape.

# Abbreviations

| | | | |
|---|---|---|---|
| bit | b | hertz | Hz |
| bits per second | b / s | hours | h |
| byte | B | kilobit | kb |
| bytes per second | B / s | kilobits per second | kb / s |
| frames per second | fps | kilobyte | kB |
| gigabits | Gb | kilohertz | kHz |
| gigabits per second | Gb / s | megabit | Mb |
| gigabyte | GB | megabyte | MB |
| gigabytes per second | GB / s | megahertz | MHz |
| gigahertz | GHz | micro | µ |
| gigahertz | GHz | seconds | s |

## 10-bit log

This refers to a 10-bit image sampling system that maps image brightness levels logarithmically rather than linearly. It is widely used when scanning film images and is now available directly from some digital cinematography cameras. The 10-bit data can describe $2^{10}$ or 1024 discrete numbers, or levels: 0 – 1023 for each of the red, blue and green (RGB) planes of the images. However, as all electronic light sensors are linear, they produce an output proportional to the light they see, in this case, representing the transmittance of the film. Sampling negative film, this means a large portion of the numbers describe the scene's black and dark areas (representing bright areas of the sceen), and too few are left for the light areas (dark sceen) where 'banding' could be a problem – especially after digital processing. Transforming the numbers into log (by use of a LUT) gives a better distribution of the detail between dark and light areas and so offers good rendition over the whole brightness range without having to use more digits. A minimum of 13-bits linear converted to 10-bit log sampling means sufficient detail in the pictures is stored to allow room for downstream grading and colour correction.

This is the basis of the Kodak Cineon and SMPTE DPX formats that are widely used in the post production and DI industries.

*See also: Cineon file, DPX, LUT*

## 1K

Short for the image size of 1024 x 778. This usually refers to a digital rendition of a full frame 35mm image. 1K can be regarded as a smaller version, half height and half width, of 2K (see below).

## 2K

Short for the image size of 2048 x 1556. This is almost the same as the QXGA computer image resolution, has 3.19 Mpixels and a 1.316:1 aspect ratio – the same as full frame 35mm film. This image size is increasingly used for digitising full frame 35mm motion picture film sampled in RGB colour space – making each image 12MB. Sampling is usually at 10-bit resolution and may be linear or log, depending on the application, and progressively scanned.

Note that the sampling includes 20 lines of black between frames because of the use of a full frame camera aperture. Thus the actual 'active' picture area is 2048 x 1536 and has a 4:3 aspect ratio. Removing the aperture creates an 'open gate' format which may have no black bar between frames – so all 1556 lines carry picture information.

There are other camera apertures, such as Academy, 1.85 and Cinemascope, which also sample at a nominal 2K size (– see Film formats).

Besides describing the image size, 2K is also often taken to imply 10-bit log sampling.

2K is often used for digital intermediates – providing enough resolution for digital film. Rather than being used just for effects shots, material for whole movies is scanned and post produced in this format. This generates large amounts of data requiring 288 MB / s, or about 1 TB / h for storage.

From 2K high quality outputs are available on celluloid by outputting to a film recorder and, by taking a 1920 x 1080 slice from the digital 2K images, for HD and onward publishing. In addition, very high quality SD and other resolutions can be produced.

*See also: DTF, Film formats, MTF*

## 4K
Shorthand for a digital image size of 4096 x 3112 – four times the area of 2K. This is specified as a digital film format but is not often used in DI: partly because scanning-in from, and output to, film recorders is slow, and the amount of data produced for the RGB images amounts to over 1.1 GB / s. The main use for this is in some film effects applications where the output shots need to be ‘seamlessly’ intercut with the original negative.

*See also: MTF*

## 4:2:2
A ratio of sampling frequencies used to digitise the luminance and colour difference components (Y, R-Y, B-Y) of an image signal. The term 4:2:2 denotes that for every four samples of the Y luminance, there are two samples each of R-Y and B-Y, giving less chrominance bandwidth in relation to luminance compared to 4:4:4.

The term 4:2:2 originated from the ITU-R BT.601 digital video sampling where 4:2:2 sampling is the standard for digital studio equipment. The origin of the term is steeped in digital history and should strictly only be used to describe a specific format of standard definition digital television sampling. However, it is widely used to describe the sampling frequency ratios of image components (RGB or Y, B-Y, R-Y) of HD, film and other image formats.

## 4:4:4
One of the ratios of sampling frequencies used to digitise the luminance and colour difference components (Y, B-Y, R-Y) or the RGB components of images. In this ratio there is always an equal number of samples of all components. RGB 4:4:4 is commonly used when sampling film (e.g. 2K, 4K)

*See also: 2K*

## AAF

The Advanced Authoring Format – an industry initiative, launched in 1998, to create a file interchange standard for the easy sharing of essence data and metadata among digital production tools and content creation applications, regardless of platform. It includes EBU / SMPTE metadata and management of plugable effects and codecs. It allows open connections between equipment where not only images and sound are transferred but also metadata that includes information on how the content has been composed, where it came from, etc. It can fulfil the role of an all-embracing EDL or offer the basis for a media archive that any AAF-enabled system can use.

After years of development it is now used in equipment from a number of manufacturers, including Quantel. With it, all history information can be shared and set-ups and decisions recreated accurately, not only on the original equipment but also on any AAF-enabled platform. The use of AAF on iQ is a real step towards true information openness and exchange. For example, it enables the generation of open archives that can be revisited as a project develops as well as enabling work to be shared in unrendered form, between platforms. Apple's Final Cut Pro is one system taking full advantage of AAF exchange with iQ.

*Website: www.aafassociation.org*

## Answer print

The answer print, also called the first trial print, is the first print made from edited film and sound track. It includes fades, dissolves and other effects. It is used as the last check before running off the release prints from the internegatives.

## Best light (pass)

A telecine transfer where the lighting is adjusted on a scene-to-scene basis to give the best results.

## Camera negative (film)

Camera negative film is designed to capture as much detail as possible from scenes. This not only refers to its spatial resolution but also its dynamic resolution. Modern camera negative stock has as much as 11 stops of exposure range and so is able to record detail in both the lowlights and the highlights which are well beyond the range that can be shown on the final print film. This provides latitude to compensate for over or under exposure during the shoot or to change the look of a scene. The latitude is engineered into the film stock by giving it a very low gamma of around 0.6.

Exposed and developed camera colour negative film has an orange tint and is low in contrast – differing greatly from the un-tinted and high contrast print film. As not only the blue, but also the red and green layers of the film are sensitive to blue light, the orange layer is added below the blue layer to stop blue light going further. All types of film stocks use orange dye but for print films it is bleached away during processing.

There are numerous stocks available. High speed stocks work well in lower lights but tend to be more grainy. The opposite is true for low speed stocks.

*See also: OCN*

## Cineon (file)

An RGB bitmap file format (extension .cin) developed by Kodak and widely used for storing and transferring digitised film images. It accommodates a range of film frame sizes. In all cases the digital pictures have square pixels and use 10-bit log sampling. The sampling is scaled so that each of the $2^{10}$ code values, from 0-1023, represents a film density difference of 0.002 – describing a total density range of 2.048, equivalent to an exposure range of around 2,570:1 or about 11.3 stops. Note that this is beyond the range of current negative film.

The format was partly designed to hold virtually all the useful information contained in negatives and so create a useful ‘digital negative’ suitable as a source for post production processing and creating a digital master of a whole programme.

*See also: 10-bit log, DPX*

## Colour timing (A.K.A. Grading)

The colour of film exposed and processed in a laboratory is controlled by separately altering the amount of time that the red, blue and green lights are used to expose the film. This is referred to as colour timing and its effect is to alter contrast of R, G and B to create a required colour balance.

In a lab, colour timing is usually applied when the edited negative is copied to the master interpositive but can be done later at other points if required. In the digital film process, colour timing is applied at any point in the process, as required. In addition there is far more flexibility for colour control with gamma, hue, luminance, saturation as well as secondary colour correction. Furthermore, the results can be seen immediately, projected onto a large cinema screen and further adjusted interactively. The images have precise colour settings to show the results as if output via film, or digitally.

*See also: Grading, Lights, Timing*

## DataCine™

Philips (now Thomson) term for telecines with data (rather than video) outputs.

*See Film Scanner*

## Data wrangling

Data wrangling is the job of managing the movement and availability of data in a digital environment such as DI, where the data mainly describes images and sound. For example, when loading new material into the workstation ready for its next session, this may not be controlled from the workstation but managed by the data wrangler. Data wrangling can become increasingly complex if the environment comprises very many separate workstations.

## DC28

SMPTE Task Force on Digital Cinema. DC28 is intended to aid digital cinema development by determining standards for picture formats, audio standards and compression, etc.

Although the HD-based digital cinema presentations have been very well received, yet higher standards may be proposed to offer something in advance of today's cinema experience.

## D-cinema

Refers to the digital distribution and projection of cinema material. High definition television and the continuing development of digital film projectors using DLP and D-ILA technology allow high quality viewing on large screens. The lack of all-too-familiar defects such as scratches and film weave – even after many showings – already has its appeal. Besides quality issues, D-cinema introduces potential new methods for duplication and distribution, possibly by satellite, and more flexibility in screening.

The SMPTE Task Force On Digital Cinema, DC28, is set up to recommend standards.

*See also: DC28, DLP-cinema, D-ILA*

## Densitometer

An instrument used to measure the density of film, usually over small areas of images. It actually operates by measuring the light passing through the film, which is a factor of transmittance, and green film will transmit more light than red or blue. Also, negative film differs from positive film. As a result, two sets of colour filters are used in measuring film density: Status M refers to the density of camera negative and intermediate stocks and Status A is used for print film.

## Density

The density (D) of a film is expressed as the log of opacity (O).

$$D = \text{Log}_{10}\, O$$

Using a logarithmic expression is convenient as film opacity has a very wide range and the human sense of brightness is also logarithmic.

*See also:Digital Fact Book: Film basics (Tutorial)*

## Digital cinematography

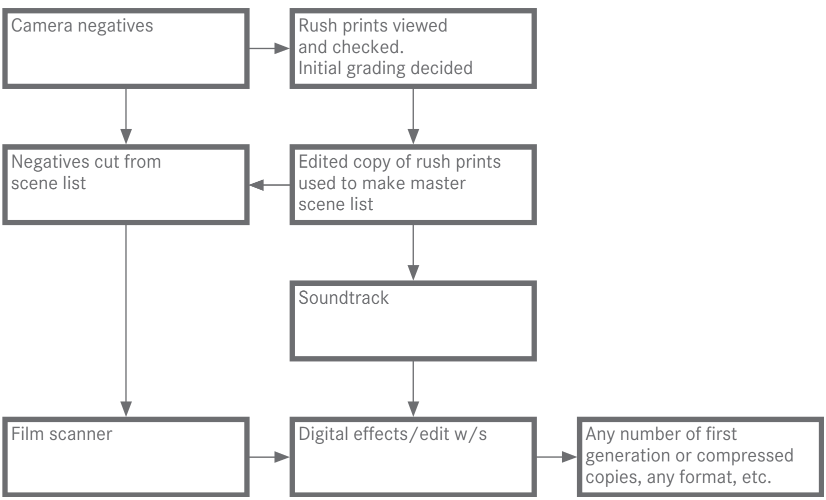
Shooting ‘film’ digitally. The cameras available are changing fast as they offer more ‘film’ features. The largest digital acquisition format currently available is HD at 1920 x 1080 pixels – slightly less than 2K (larger formats are in the labs). However, this image format has already been used with great success on whole features as well as an alternative to 35mm and Super 16mm for television. Camcorders used to date have been Sony’s CineAlta and Panasonic’s Varicam. All have film-style attachments such as feature lenses.

There are a number of areas that are seen by some as drawbacks: television front-end processing on some cameras limiting the room for downstream adjustments, the use of compression, less latitude (compared with camera negative), increased depth of field due to using smaller light sensors than a 35mm frame and inability of over- or under-crank. These have mostly been addressed in the more modern digital cinematography cameras which offer unprocessed RGB outputs, wider dynamic range and variable frame rate (Varicam).

*See also: Chapter 4 (Acquisition), VFR*

## Digital distribution

If supplying digital cinemas (D-Cinema) or other digital media, the production of the multiple distribution copies from a DI produced digital master is quick and easy. Unlike film which can only be reproduced by one-to-one contact (hence all the interpositive and internegative copying to build up the numbers), digital media can reproduce by a one-to-many operation. All distribution copies, master copies, etc., can be made at one time. This is quicker, cheaper and avoids any wear on the master version.



The distribution can use digital channels. Currently DVDs are distributed and copied to hard disks at digital cinemas. There has also been direct distribution via satellite and broadband. With relatively low data speeds delivery can be overnight, whereas high data speeds can be used for live showings direct from the studio / distributor.

## Digital Intermediate (DI)

Generally digital intermediate refers to a digital file or files resulting from a scan of a film (usually negative) original that is used for the editing, effects and grading / colour correction. It is the material that is used in DI labs and constitutes the whole film. As such it should carry all the useful information that is contained in the OCN to provide both the latitude and sharpness of the original for which scanning at 2K resolution, 10-bit log is usually considered ideal.

It could also apply to material directly recorded from a digital TV camera – from DV through to HD and digital cinematography cameras.

## Digital lab (A.K.A. DI lab)

The film lab accepts exposed footage and eventually delivers edited and graded masters – in the form of internegatives – to the production labs to produce large numbers of release prints. Although the boundaries may vary, generally the digital lab accepts developed camera negative (OCN) and outputs the edited and graded internegative master for a whole feature. However, the operational and decision processing between differ greatly from the film lab, not least because of the interactive nature of the digital operation. In the digital lab, decisions can become instant on-screen realities and seen in full context as they are prepared – no waiting as in the 'chemical' lab. Grading, dissolves, cuts and effects can be seen immediately and on a big screen – if needed. The interactive process can be more creative and gives complete confidence that the decisions work well.

Using large-scale digital storage means that long sections of finished material can be sent for output to the digital lab's film recorder, exposing 1000ft reels at a time.

## D-ILA

Digital Image Light Amplifier. Technology developed by Hughes-JVC for video projection up to large screen size. The scanned electronic images are displayed on a CRT which has infrared phosphors. The resulting IR image is used to control the reflection of the projector light according to the intensity of the IR. The technology has been used up to cinema screen size to show 'digital movies' with full 2K resolution.

*Website: http://www.jvcdig.com/technology.htm*

## DLP™

(Texas Instruments Inc) Digital Light Processing is the projection and display technology which uses DMDs as the light modulator. It is a collection of electronic and optical subsystems which enable picture information to be decoded and projected as high-resolution digital colour images. DLP technology enables very compact, high brightness projectors to be made and more than one million systems had been sold by early 2002. It is used in high definition television sets and large screen monitors.

*See also: DLP Cinema, DMD*
*Website: www.dlp.com*

## DLP Cinema™

(Texas Instruments Inc) DLP Cinema technology is a version of DLP technology specifically developed for digital electronic movie presentation. It contains extended colour management and control, and enhanced contrast performance. By the middle of 2002 more than 100 DLP Cinema technology-based projectors had been installed in commercial cinemas around the world showing 'first run' feature films.

*Website: www.dlpcinema.com*

## DMD™

(Texas Instruments Inc) Digital Micromirror Device. A silicon integrated circuit used to modulate light in a wide variety of applications. The most common use is in electronic projection systems where one or more devices are used to create high quality colour images. The device is a memory circuit whose elements are arranged in a display format array. Each element contains a square aluminium mirror which can tilt about its diagonal axis. The content (charge) of the memory cell causes the mirror to move from one tilt position to the other. By changing the memory data, the mirror can be switched very rapidly to create pulses of light whose duration causes the pixel to appear at a particular brightness. DMDs are produced at different sizes according to the resolution required. The smallest contains over 500,000 mirrors. Devices with 1280 x 1024 (SXGA) have been widely used in digital cinema applications.

*See also: DLP, DLP Cinema*
*Website: www.dlp.com*

## DPX

SMPTE file format for digital film images (extension .dpx) – ANSI / SMPTE 268M-1994. This uses the same raster formats as the Cineon file format but differs in its file header. Unlike Cineon DPX can have both log and linear sampling – which should be indicated in the file header.

*See Cineon file*
*Website:www.cineon.com/ff_draft.php#tv*

## DTF and DTF-2

Digital Tape Format for storing data on half-inch cassettes at high data density on the tape and offering fast read and write speeds. Generally it is used for long-term file-based storage and the modern DTF-2 can store 200GB (uncompressed) per cassette with a sustained data rate of 24MB / s. In television / digital film applications DTF is often used as the archive in a facility with networked workstations.

## Dynamic range

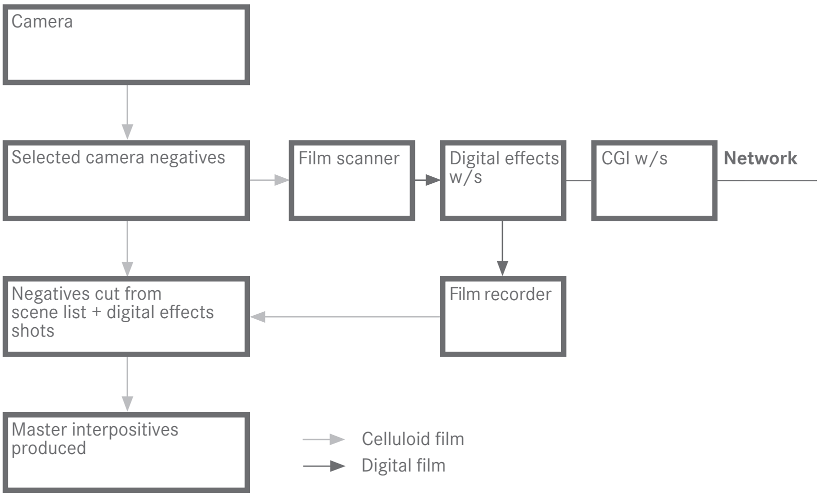
The measurement of the range of brightness in a scene expressed as a ratio or the $\mathrm{Log}_{10}$ of the ratio. Typically the lighting cameraman will try to keep the scene to less than 40:1 (Log = 1.6) to avoid loss of detail in the print. A 100:1 (Log = 2) contrast range in the scene is a typical maximum.

*See also: Cineon file*

## Effects (digital)

Any film editing, other than cuts, has traditionally required the use of a film optical lab where dissolves, wipes and any compositing work for making effects shots can be carried out. The techniques are highly refined but lack interactivity and are not lossless – hence the jump in colour and quality before and after a film dissolve. Such effects work is now increasingly undertaken in digital equipment. For this the appropriate camera negative footage is scanned and stored – usually onto disks. This is then digitally processed and composited with other images, computer graphics, etc., in an effects workstation, which can be lossless irrespective of the number of effects layers, provided that the images remain uncompressed, and the results can be seen immediately. If working in a chemical lab, the completed effects shots are then output to a film recorder to produce new negative footage to be cut in with the rest. If working with digital intermediates, the processed image data is added directly to that of the rest of the ‘film’.

**Digital film effects**




## Exposure

Exposure refers to the amount of light that falls on a film or light sensor. In a camera this is controlled by both time with the shutter, and the effective lens aperture, referred to as the F-number or T number.

*See also: Density, Stop*

## Film formats

Unlike pre-HD television which, until recently, had only two image formats, 525 / 60I and 625 / 50I, 35mm film has many. Of these the most common are Full Frame, which occupies the largest possible area of the film, Academy and Cinemascope. The scanning for these is defined in the DPX file specification as follows:

| Scanning Resolution | Full Frame | Academy | Cinemascope |
|---|---|---|---|
| 4K | 4,096 x 3,112 | 3,656 x 2,664 | 3,656 x 3,112 |
| 2K | 2,048 x 1,556 | 1,828 x 1,332 | 1,828 x 1,556 |
| 1K | 1,024 x 778 | 914 x 666 | 914 x 778 |
| Aspect Ratio | 1.316 | 1.372 | 1.175 |

These scan sizes generally represent the valid image size within the total frame size indicated by full frame. It is generally considered that all scanning is done at full frame size as this avoids the complexity of adjusting the scanner optics or raster size with risks associated with repeatability and stability.

In addition, different camera apertures can be used to shoot at different aspect ratios. All these (below) are 'four perf' (a measure of the length of film used) and so all consume the same amount of stock per frame.

| Format | Width mm | Height mm |
|---|---|---|
| Full Frame | 24.92 | 18.67 |
| Academy | 21.95 | 16.00 |
| Cinemascope | 21.95 | 18.60 |
| 1.66:1 | 21.95 | 13.22 |
| 1.75:1 | 21.95 | 12.54 |
| 1.85:1 | 21.95 | 11.86 |

There are many more 35mm formats in use.

## Film recorder

Equipment which inputs digital images and outputs exposed film, usually a timed internegative. Currently CRT-based recorders are the fastest, outputting 2K images onto camera negative stock at the rate of one per second. The fastest laser-based units take 2.2 seconds for full aperture images.

*Websites: www.arri.com*
*www.celco.com*

## Film scanner

A general term for a device that creates a digital representation of film for use in digital intermediate work or digital VFX. They should have sufficient resolution to transfer the required detail of the OCN. In the case of DI the output is used as a 'digital camera negative'. Generally, high quality 2K images are sufficient, which means they are oversampled and resized in the scanner to 2K, and must retain the full OCN contrast range. For digital VFX work the images must be good enough so that the film-digital film chain can appear as an essentially lossless process for cutting the VFX footage back into the original footage. Here 3K or 4K scans are often used. The scanner output is data files rather than the digital video that would be expected from a traditional telecine.

For DI the material is often transferred with a best light pass and the linear electronic light sensors, often CCDs, have to sample to at least 13 bits of accuracy (describing 8192 possible levels). Using a LUT, this can be converted into 10-bit log which holds as much of the useful information but does not 'waste' data by assigning too many levels to dark areas of pictures.

Note that this is different from using a telecine to transfer film to video. Here, normal practice is to grade the film as the transfer takes place so additional latitude is not required in the digital state so 10 or 8 bits linear coding is sufficient.

## Gamma

Gamma generally relates to contrast but it has several meanings. In the video world a CRT television monitor's brightness is not linearly proportional to its driving voltage. In fact the light output increases rapidly with drive. The factor, gamma, of the CRT, is generally calculated to be 2.6. This is compensated for in the camera by a gamma of 0.45 giving an overall gamma of 0.45 x 2.6 = 1.17 – adding overall contrast to help compensate for domestic viewing conditions.

In film, gamma describes the average slope of the D / Log E curve over its most linear region. For negative stocks this is approximately 0.6, for intermediate stocks this is 1.0 and for print stocks 3.0. This gives a system gamma of 0.6 x 1 x 3 = 1.8. This overall boost in contrast is much reduced due to flare and auditorium lighting conditions.

*See also: Internegative, Interpositive*

## Grading (film and digital)

Individually adjusting the contrast of the R, G and B content of pictures to alter the colour and look of the film. Traditionally this has been controlled in film labs by adjusting the amount of R, G and B light to alter the exposure of print to negative – known as colour timing. This is commonly applied during copying to interpositives in order to achieve a shot-to-shot and scene-to-scene match by altering the overall colour balance of the images. This is not a hue shift but a control of the proportions of R, G, and B in the final images. For film being transferred for video post production in a telecine, grading using lift, gain and gamma is executed shot-by-shot, as the film is transferred.

Today there is a growing move toward digital grading which involves one continuous best-light pass through a film scanner with the result being stored to a data server. Grading then takes place purely in the digital domain and without film in the scanner. Not only does this free up the scanner for other work but it also involves far less film handling and so is quicker and involves less risk of damaging the film. Note that digital grading requires that there is sufficient latitude in the digital material to allow a wide range of adjustment. This involves using either linear sampling at 13 bits or more, or 10-bit log DPX / Cineon files.

## GSN

Gigabyte System Network (GSN) – a relatively new networking technology that potentially delivers 800 MB / s performance.

*See Chapter 5*

## Handles

Extra frames included before and after the wanted footage. This extra material is usually included in an EDL so that there is some leeway to alter an edit at the conforming stage. Making such alterations can become far easier in a non-linear environment. Extra film footage 'handles' help to ensure that the mechanical aspects of telecines have time to settle down after a splice edit.

## HD-SDI

High Definition Serial Digital Interface (SMPTE 292M) places uncompressed real-time digital HD television pictures and sound onto a single co-axial cable. HD-SDI is used for making connections in HD studios and post facilities. There is a wealth of infrastructure products, such as routers, recorders, etc. that can work with HD-SDI. Its serial bit-stream runs at 1.485 Gb / s to carry up to 10-bit Y,Cr,Cb images in component form as well as audio and ancillary data. It extends the use of the coax cable and BNC connector 'plug-and-play' interface familiar to television operations for decades. The interface is also specified for fibre for distances up to 2 km.

HD-SDI has also been adapted for carrying high-speed data and realtime RGB HD signals using two links together.

*See also: HSDL*

## HSDL

The High Speed Data Link is typically used to transfer uncompressed 2K, 10-bit RGB digital film images in a facility. The data volumes involved are very large; each image is 12MB, and at 24fps this data amounts to 288MB / s.

HSDL provides an efficient transport mechanism for moving and sharing data between applications. It uses two SMPTE 292M 1.485Gb / s serial links (HD-SDI) to provide nearly 3Gb / s bandwidth and typically transfers 2K at 15-20fps, although realtime is also possible. Use of the SMPTE 292M data structure means the signal can be carried by the HD-SDI infrastructure – cabling, patch panels and routers that may already be in place for HD video.

*See also: 2K, DTF, HD-SDI*

## Internegative

As a part of the chemical lab film intermediate process internegatives are by contact printing from interpositives. These very much resemble the cut negative. The stock is the same as for interpositives: slow, very fine grain with a gamma of 1, and the developed film is orange-based. Again, to increase number, several interpositives are copied from each internegative. These are then delivered to production labs for large-scale manufacture of release prints.

## Interpositive
This is a first part of the chemical lab intermediate process where a positive print of film is struck from the cut (edited) camera negative. Interpositives are made by contact printing onto another orange-base stock. In order to preserve as much detail as possible from the negative, including its dynamic range, interpositive material is very fine grain, slow and has a gamma of 1. During the copying process, grading controls are used to position the image density in the centre of the interpositive material's linear range. As a part of the process of going from one camera negative to, possibly, thousands of prints, a number of interpositives are copied from the negative.

## Latitude
Latitude is the capacity of camera negative film to hold information over a wider brightness range (up to 12 stops) than is needed for the final print. This provides a degree of freedom that is needed because it is impossible to see if the exposure is totally correct until the film comes back from the laboratory – long after the set has been struck and everyone has gone home. Latitude provides room for later adjustment in printing to compensate for over or under exposure. Historically, digital cinematography has recorded a smaller brightness range but adds the possibility to see the results immediately and make any required adjustments at the shooting stage. This procedure can reduce the need for a very wide latitude (which, in any case, cannot extend to the release prints) by ensuring the lighting and set-ups are always correct at the shoot.

The more recent digital cinematography cameras have extended their brightness range to nearly equal that of camera negative.

*See also: Camera negative*

## Lights
*See Printer lights*

## LUT
Look-Up Table. This refers to a table of conversion factors that are used to transfer information between two differing but related systems. For example, there is often a requirement to look at digital image material to see what it looks like on a CRT, digitally projected and projected via film – all of which have different characteristics. A fast and relatively simple way to process the digital material so that it looks as it should on all displays is to multiply each digital pixel level by a unique number stored in a LUT that corresponds just to that value. Thus a linear CCD output can be processed to drive a CRT which has a highly non-linear 'gamma' characteristic. In addition, it provides a path between linear electronically scanned images and the logarithmic world of film.

## MTF

The Modulation Transfer Function is a measure of the spatial resolution carried by film – akin to frequency response in electronic images. To assess this, the film is exposed to special test images comprising sine wave bars of successively higher frequencies. The results on the processed film are assessed by measuring its density over microscopically small areas to obtain peak-to-trough values for the different frequencies. These results should then be corrected to allow for the response of the lens, the test film itself and any D / Log E non-linearities.

In a practical film system, the film images pass through many components including the camera lens, intermediate stocks and contact printing to the projection lens. Each of these has its own MTF and the system MTF ($MTF_{system}$) can be calculated as follows.

$MTF_{system}$ = MTF1 x MTF2 x MTF3 etc…

Note: once images are digital, they need not suffer any further losses until projected. With good digital engineering, the compounding of MTF that occurs in optical processes need not apply within the digital domain.

*See also: Resolving power, Digital Fact Book MTF*

## Negative

Film that shows the shot scene as negative images. Negative material is used in several stages of the traditional film production chain that culminates in release prints.

*See also: Camera negative, Internegative, OCN*

## Neutral density filter

Optical filter that reduces the amount of light entering a lens but does not impose any change of colour. Applications include the use of higher speed film in bright conditions, permitting the use of wider apertures to reduce depth of field to throw the background out of focus and controlling the amount of light without relying solely on the lens aperture. Graduated ND filters can be used to evenly expose unbalanced lighting.

## OCN

Original Camera Negative – the exposed and developed film from the camera. This is the highly valuable only record of the action and it carries a very wide contrast range.

*See also: Camera negative*

## One light (pass)

In a one light telecine transfer all the material is transferred using a mid setting that may not correctly resolve all the low or highlights. One lights are often used to transfer rushes for offline.

*See also: Best light*

## Perf

Short for perforations. It is a way to describe some information about the format of images on 35mm film by how many of the perforations, or sprocket holes, are used per image. For example, Full Frame is 4 perf.

## Printer lights

A projectable print from the camera negative is usually made by contact printing. The intensity of the light used to expose the print film can be controlled and in this way corrections can be made for under / over exposure of the negative. To enable colour corrections to be applied during the printing process the exposing light is split into red, green and blue components each of which can be controlled independently. There is an internationally agreed scaling for the numbers used to define the exposures used in this process to permit film labs around the world to produce near identical results.

A change of 1 in the 'light' value represents 1 / 12th of a stop adjustment in print exposure. From the camera negative perspective 7 printer lights are equivalent to one stop of camera exposure.

*See also: Colour timing, One light pass, Timing*

## Print film

Film stock designed specifically for distribution and exhibition at cinemas. Unlike negative and intermediate film, it is high contrast and low on latitude. This is designed to give the best performance when viewed at cinemas.

Obviously the release print has to be clear of the orange base so this is bleached out during processing.

## Projectors (digital)

Digital projectors input digital images and project them onto cinema-sized screens. Huge advances in this technology in the last five years have been one of the driving forces behind digital film. There are two prominent technologies in the large projector area, D-ILA from JVC-Hughes and DLP from Texas Instruments. The viewing public is generally very impressed with the results as without film's scratches, dirt and weave, they are treated to consistently high quality results.

*See also: DLP, D-ILP*

## Resolving power

The resolving power of film is a measure of its maximum spatial resolution. To assess this, the film is exposed to special test images comprising sine wave bars of successively higher frequencies. The results on the processed film are then judged by a panel of viewers – making them somewhat subjective.

*See also: MTF*

## Selects rolls/reels

A roll / reel of film that comprises only the chosen shots. This is typically a cut version of the OCN and it includes some footage on either side of the chosen material to allow room for adjustments and other 'mechanical' considerations. Using a selects roll means that the film scanning or telecine operation is more straightforward and does not involves so much spooling and changing of reels and a best light pass can be carried out continuously. The downside is that it involves more handling of the OCN and so increases the risk of film damage.

## Status M and Status A

*See: Densitometer*

## Stop

A ratio of amount of light where one stop represents a doubling or halving of the light. The operating range of film and electronic light sensors, such as CCDs, are quoted in stops. Typically, a camera's shutter speed and the lens's aperture setting restrict the light arriving at the sensors / film so the mid brightness of the required scene corresponds to the middle of the sensor's or film's sensitivity range for the required shutter speed.

Stops are simply the expression of a ratio, not absolute values. As they represent doubling of light, they are actually powers of 2. So

| |
|---|
| 1 stop = x 2 |
| 2 stops = x 4 |
| 3 stops = x 8 |
| 4 stops = x 16 |
| 12 stops = x 4096 |

Note that cine lenses are often marked in f-stops (white) and T-stops (red). The former is the relationship of focal length / aperture and does not take into account how much light is lost within a lens. T-stops do and represent the real working values. So, on a lens that loses a full stop in transmission (i.e. a 50-percent loss), f / 8 would result in the same exposure as T11. F and T values are usually close on prime lenses but zoom lenses show a greater difference.

## TAF

Telecine Analysis Films are designed to provide a solid analytical reference for the technical set-up of telecines or film scanners. For colourists they offer a means for centring the telecine / scanner controls as a good starting point for grading client film. TAFs are available to suit the various types of film stocks that are widely in use – e.g. Kodak Vision, Premier.

## Technical grade

As 'best light' but a technical grade is often a lower contrast scan to ensure no clipping of high or lowlight detail.

## Timing and Timer

Timing refers to the amount of the separate R, G and B lights that are used to expose film in a laboratory as a part of the grading process. The term is sometimes also applied to colour correction (grading) during telecine transfers. The timer is one who decides and controls the lights' timing.

*See also: Colour Timing, Grading, Lights*

## WYSIWYG

What You See Is What You Get. Usually, but not always, referring to the accuracy of a screen display in showing how the final result will look. For example, a word processor screen showing the final layout and typeface that will appear from the printer. Or in a grading suite, does the monitor show exactly how the film will look when projected digitally, or with film? This subject requires more attention as edited masters are now commonly output to a wide variety of 'deliverables' such as SD video, HD video, DVD, VHS, as well as digital projection and film. Issues such as colour, gamma and display aspect ratio may need consideration.

The term is also used to describe the immediacy of using digital cameras where the result (what you get) can be seen during the shoot – so allowing adjustments, such as lighting, to be optimised at the shoot – leaving less work for the lab.

## VFX

Short for Visual Effects – effects that are added digitally to the images through compositing, keying / matting, etc.

## Y, R-Y, B-Y

These are the analogue luminance, Y, and colour difference signals (R-Y) and (B-Y) of component colour space. Y is pure luminance information normally made by adding the red, blue and green signals of the colour detectors together, whilst the two colour difference signals together provide the colour information. The latter are the difference between a colour and luminance: red – luminance and blue – luminance. The signals are derived from the original RGB source (e.g. a camera or telecine).

The Y, (R-Y), (B-Y) signals are digitised to make 4:2:2 digital component signals.

Care should be taken when using RGB-only post production systems to work with HD Y, R-Y, B-Y material. Since Y, R-Y, B-Y colorspace is actually larger than RGB and Y, R-Y, B-Y includes headroom above white and footroom below black, some RGB software systems 'clip' Y, R-Y, B-Y highlights into RGB space resulting in loss of information. For example in a Y, R-Y, B-Y system white is 235 (8 bit) or 940 (10 bit) but white values up to 255 (8 bit) or 1024 (10 bit) can be described. RGB maps white directly to 255 (8 bit) or 1024 (10 bit) without headroom. This is most commonly seen as burnt out detail in highlights.

*See also: 4:2:2,*