ARRI TECHNICAL NOTE P-1008

What is 3:2 Pulldown?
July 20, 2000

Summary
This note describes the 3:2 Pulldown process used in US Telecines to transfer 24 fps film to 29.97 fps video.

Overview
The 3:2 Pulldown process is a method to map the 24 frames per second (fps) that are captured during film production onto the 29.97 fps of a 525 line TV system, like the one used in the United States. This note concerns itself only with the 3:2 Pulldown process as used in the United States.

Why 24 fps Film?
Even though in the early days of film production many different fps rates were experimented with, most footage was captured at 18 fps as a compromise between flicker and raw stock cost. This changed when sound was introduced: To achieve reasonable sound quality the magnetic audio recorder had to move faster than 18 fps. 24 fps was adopted for the audio recorder and for the film camera. This has remained the speed of choice in the United States.

Why 29.97 fps Video?
The fps of video playback in the US was originally 30 fps. This speed was chosen to make a possible hum bar stationary in the picture, thus making it less objectionable. When color was introduced, the color information was superimposed over the B/W signal to ensure that the television broadcast could still be viewed on the old B/W sets. To make this work, the playback frequency had to be changed from 30 fps to 29.97 fps. Almost all NTSC 525 line video recording and playback in the United States occurs at 29.97 fps.

What is a Video Field?
Each video frame consists of 2 video fields. One video field contains all the even, the other all the odd lines of the frame. Since NTSC video runs at 29.97 fps, there are twice as many (59.94) fields every second.

24 Fps Film to 30 Fps Video
In order to understand how 24 fps film is transferred to 29.97 fps video, lets first look at a simpler task: transferring 24 fps film to 30 fps video (= 60 video fields per second).

The solution that was adopted was to double up some of the 24 film frames each second and to distribute them in a repeating sequence into the 60 video fields. This sequence, repeating every 4 film frames, is called “3:2 Pulldown”. One film frame is transferred into 2 video fields, the next one into 3 video fields, the next one again into 2 video fields, and so on (see graphic). The four film frames of this sequence are called A, B, C and D. The corresponding video fields are called A1, A2, B1, B2, B3, C1, C2, D1, D2 and D3.

24 Fps Film to 29.97 Fps Video
To transfer film to the actual video rate of 29.97 fps, the film playback in telecine is slowed down by 0.1% to 23.976 fps. All US telecines play 24 fps film back at 23.976 fps. 29.97 fps is 0.1% slower than 30 fps, and 23.976 fps is 0.1% slower than 24 fps. 23.976 frames per second will now fit nicely into 29.97 frames per second if transferred at the 3:2 Pulldown interval.

Why Does This Matter?
The intricacies of the 3:2 Pulldown have little importance to the filmmaker (apart from the aesthetic aspects, which I dare not discuss here), unless the attempt is made to record the video from the video assist camera with Timecode for frame accurate editing purposes.

To ensure that the video and Timecode from the video assist match the video and Timecode from the telecine, the film camera on the set should be run at 23.976 fps. The Arriflex Integrated Video System (IVS) is then capable of performing the exact same 3:2 Pulldown that a telecine would perform, and the images and Timecode recorded on the set will match the images and timecode from the telecine frame accurately.

Please note that this is only relevant if FRAME ACCURATE editing from the video assist material is required. If frame accuracy is not needed it is possible to use other fps rates and any video assist with an external timecode window burner.

What About Europe?

The frames per second situation in Europe is far simpler, since European television runs at exactly 25 fps (derived from the 50 Hz power line frequency, I presume), and film is also shot at 25 fps. Film shot at 24 fps will simply be sped up to 25 fps in telecine, without any detrimental effects.

For more information on this issue, please contact Marc Shipman-Mueller at
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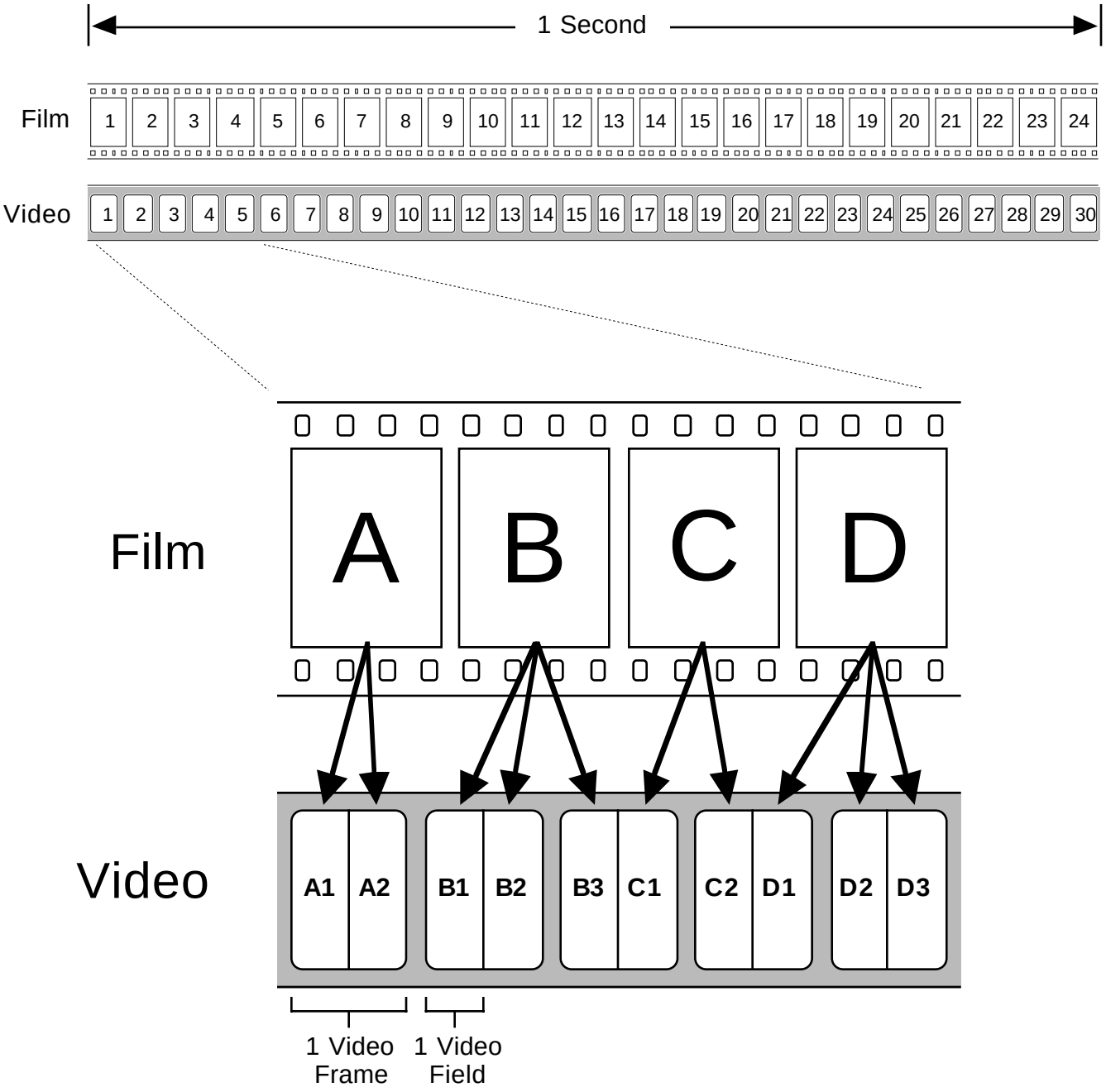
1 Second
Film
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Video
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Film
A
B
C
D
Video
A1 A2 B1 B2 B3 C1 C2 D1 D2 D3
1 Video Frame
1 Video Field