Pulldown Revisited: 60i Or 24p?

Why 24 fps from 60i just isn't the same as from 24p native

By C.R. Caillouet

If a camera such as Panasonic's AJ-HDC27 VariCam records at 60 fps, why should I capture at 24 fps? Surely I can extract 24 from 60 and keep that 60 fps original in case I need footage in slo-mo, right?

Yes, you could do that—but you may not really want to.

The answer here requires us to bend our minds a bit around what's really happening when we capture and view images. It also requires us to think about human conditioning and adaptation.

When we capture in a camera, we set the frame rate to give us a consistent time between frame captures, then we set the exposure time with the shutter to control the amount of time of the capture.

The shutter-open time can vary from the fastest time that the camera can handle to very close to the time between frames.

We can select a value between the two shutter limits based on the amount of exposure time, the amount of blur in the image and the amount of strobing that we desire in moving objects.

The range of impressions from maximum blur to maximum strobing allows a filmmaker to affect the emotions of a viewer. In this manner, one can emphasize motion with blur or make the viewer uncomfortable with lots of strobing.

I guess this is as good a time as any to clarify some terminology.

Motion strobing is the effect caused by limiting the shutter opening time to less than the entire frame time. Think about a camera panning across a flagpole. If the shutter were open for the length of a frame, which a video camera can come very close to, then the pole would blur across the entire frame.

If the shutter were only open for half of the frame time, then the pole would blur across half the distance, then jump to its starting position in the next frame. (The exposure time can happen at the beginning or end of the frame time but the effect is the same.)

The jump is referred to as motion strobing and is more noticeable for shorter exposure times at the same frame rate (narrow shutter angle in film terms) and for faster panning speeds. As it becomes more noticeable, it's often referred to as stutter.

Motion strobing (or stutter) is a periodic effect that's regular in occurrence. I'll use the term "judder" to refer to a type of strobing that's not necessarily regular. We'll get there in a minute.

When we play back captured images, we can play them back at the original frame rate or we can duplicate the frames and flash the same image

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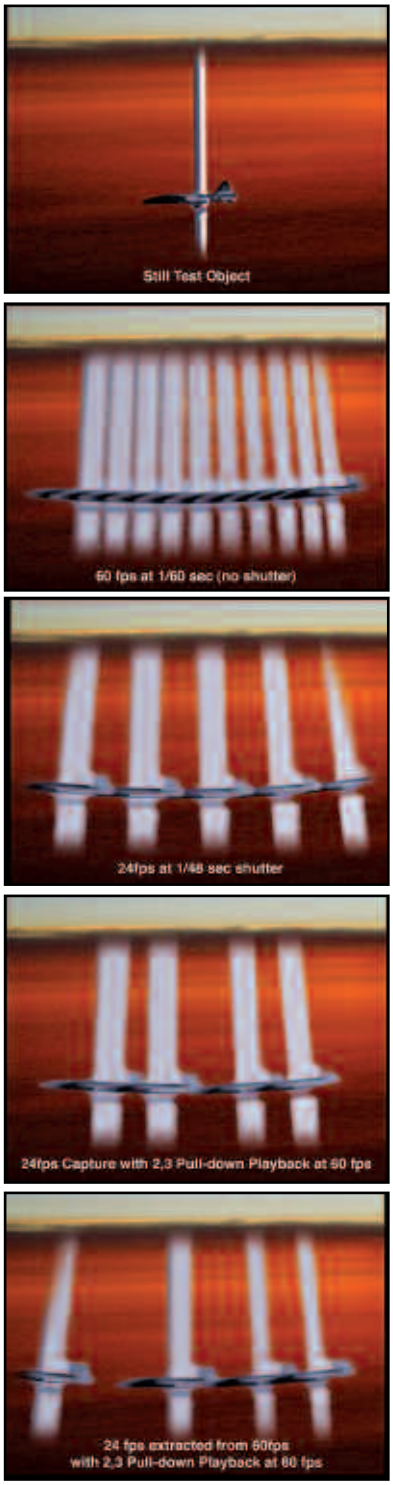

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This sequence of images illustrates the results of 60 fps and 24 fps capture and playback variations. The image at top is the test object at rest, a small airplace attached to a pendulum, captured as it travelled across the screen. All other images are composites of frame sequences.

There is some variation in the width of the pendulum bar in the capture, but the true 24 fps capture shows distinctly wider bars because of additional motion blur. The second and third images show 60 and 24 fps capture.

The fourth image shows the irregular playback caused by 24->60 conversion using 2.3 pull-down.

The fifth image shows the additional irregularity that results from a 24 fps extraction from 60 fps original footage, followed by a 2.3 pull-down conversion back to 60 for standard television distribution. This does not take into account any problems from the use of interlaced video.

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two or three times for one frame time.

The reason for repeating frames has to do with two reactions in our brains:

First, there is a minimum refresh rate required to convince us that we are seeing continuous motion. Depending on the type of motion, that minimum rate might be between 12 and 24 frames per second (fps).

The minimum rate doesn't necessarily impart a feeling of realism to us, but it does make us think that the object motion is believable. A higher frame rate might give us a more realistic impression, but 24 frames works for many applications.

There's also a limit called the flicker fusion threshold. If still pictures are flashed on a screen and removed quickly, we perceive the flicker up to 50 or 60 flashes per second. Our perception of flicker is affected by conditioning, so people who grow up in 50 fps countries tend not to notice flicker in 50 image-per-second sequences, whereas those of us in 60 fps countries are bothered by 50 flashes per second. Flicker is also more noticeable at the higher brightness of television displays, compared to film.

Film projectors deal with the discrepancy between the minimum acceptable frame rate and the flicker threshold by doubling or tripling the display rate with repeated frames.

Repeated frames are regular effects; they don't affect the spacing of each unique frame in time. But if we try to convert from film's 24 frames to video's 60 fields or frames, we either have to do some mighty sophisticated motion analysis and prediction or we need to use a cadence or irregular sequence of repeated images.

The technique of pulldown was developed in film-to-video transfer devices in the early days of television. A television camera scanned a film frame alternately for two or three vertical scans, then the film was "pulled down" during a blanking period, and the next film frame was exposed to the camera.

The result was a continual video sequence of first two and then three repeated images of the film frames. If the video system used interlaced frames (half of the lines in the image are scanned in each vertical pass), then some of the video frames contained complete film frames and some contained portions of two adjacent film frames.

If the viewer saw the video sequence played back with the two/three cadence, then motion in the film scene was modified by a new irregular judder that occurred 12 times a second, causing the flag pole in the above example to alternately move normally and slow down.

Again, human adaptation plays a role in our perception of the judder effect. Those of us who grew up watching film transfers to 30-frame video think that judder is normal for films on video. But those folks who grew up in 50 fps countries find pulldown annoying.

So what does this have to do with shooting at 60 fps and extracting 24 frames in each second? The short answer is that none of us are adapted to watching motion captured and displayed that way. In the pulldown discussion above, the original frames were captured at even intervals and then displayed at uneven intervals, and we eventually got used to it, so it doesn't affect, at least, some of us.

But if we capture a sequence at 60 fps and alternately drop one or two frames to get to 24 frames a second, we'll have effectively captured at uneven intervals.

If we then play that sequence back at a multiple of 24 fps, we'll preserve the uneven capture interval. If we display it as a pulldown stream, we introduce different irregularities at capture and display, thereby causing multiple judder effects to be cascaded.

In either case, we introduce motion artifacts that no one is adapted to, and the results on viewer emotions are unpredictable. The effects are more evident on big screens.

In addition, capturing at 60 fps limits us to 1/60-second shutter. If we were shooting at 24 with a 180 degree shutter, we would have 1/48 second. Many shooters are accustomed to stretching the shutter to above 200 degrees (longer than 1/48 sec) to compensate for the absolutely crisp all-on/all-off shutter of the video camera. Going to 1/60 sec takes you in the other direction (144 degrees.) And you lose at least 1/3 stop.

Bottom line? Just because you can, doesn't mean that you should! HDVP