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The Timing Logic of the Mintron Integrating Video Camera

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Introduction

The Mintron (Model 12V1E) is a video camera with an integrating capability. That is, one can set an internal menu to (among other things) establish an integration ratio (e.g., x1, x2, x4, x6, …x128). The number selected refers to the number of video fields that will be integrated. A field is 1/60 sec, while two successive fields make a frame (fields are even then odd scans of the sensor, so a frame (at 30 frames/sec) is a complete image).

There is little description available for how the Mintron works, either in terms of its logic, or its hardware. This report concentrates on the details of the effects of the Mintron integration relevant to timing astronomical events (e.g., stellar occultations). Previous work (http://menkescientific.com/videocamcompare.pdf) showed that the Mintron in fact does perform qualitatively accurate integrations of low brightness fields.

I would note that Gerhard Dangl (http://www.dangl.at/index.htm) has done a similar timing analysis on the WAT-120N integrating camera.

Test Setup

Measuring the behavior of the Mintron requires an accurately known method for producing any brightness change in a target at known times. The method chosen is a variation on the setup often used in astronomy to measure occultations. Specifically, the Mintron is aimed at a dark field containing a target LED of adjustable brightness. The Mintron video output feeds through a so-called Kiwi OSD (On Screen Display). The Kiwi is a device that uses a GPS sensor to detect the UTC time to an accuracy of about 1us. This time is used to calculate the beginning and end of each video field, and is electronically pasted onto each video field in human readable form. The time stamped video is then sent to a camcorder.

In later analysis, the camcorder was used to play back the tape into a frame grabber into a PC. The PC runs VirtualDub, a freeware program that converts the video to an AVI file. The AVI file was then evaluated using Limovie, a freeware program that analyzes each field to measure designated stars (or other target) and backgrounds. LiMovie also allows the observer to examine each field, including reading the GPS time of each field. The LiMovie produces a text file of the results that can be evaluated in an Excel spreadsheet. Both programs are used extensively in the astronomical community.

The target for these tests is a pinhole LED flasher whose brightness can be adjusted. The LED is driven by a custom PIC controller that is triggered by the GPS timing signal taken from the Kiwi. The GPS produces one pulse per second (1pps), beginning at the UTC second. Because the effects of the Mintron integration can last for more than one second, the controller selects every nth pps for its trigger (most tests were done at 5 second intervals). When triggered, the controller immediately (within 100us) produces an output pulse of controlled duration (in increments of field durations of 1/60 sec=16.66ms). For convenience in testing, in some tests, alternate pulses were doubled in duration.

I used an LED as a positive target "flash", and will usually refer to that. However, the logic is the same for a negative flash, i.e., a diminution of brightness, as in an occultation.

Basic Logic of the Integrating Mintron

The first point to recognize is that an analogue video camera has only a limited output amplitude range, usually thought of as about an 8bit (x256) range. Therefore, if the camera literally integrated, a two bit brightness at x1 integration would saturate the camera at x128 integration. In practice, the camera uses an automatic gain control to limit the brightness range, in effect averaging the signal during the integration period and highlighting departures from the average across the image.

At first thought, an integrating camera might be expected to run as a "rolling average". That is at x8 the camera would take eight successive fields, average them, and output the average. As successive fields occur, the oldest field would be dropped from the stack, and the newer one averaged in. If a target flash lasted longer than one field, in the resulting video one would see the target brightening in successive fields as the camera integrates. While this would be a plausible and desirable method of operation, it is NOT how the Mintron works.

The testing showed clearly that the Mintron operates very differently. Using x8 as the example, the Mintron will integrate (i.e., average) eight successive fields, and will then output the result for the next 8x16.66ms=133ms while internally integrating the next 8 fields. The Mintron establishes successive integration periods.

The testing also showed that when not integrating (i.e., at x1) the Mintron behaves exactly as most video cameras. There is no internal delay other than that associated with normal video operations, or with the integration behavior discussed below.

Note that in the tests reported here, the test flash was tied exactly to the 1pps. However, the Mintron internal timing is operating at close to but not exactly 60 fields per second, while the 1pps is precisely once per second. Thus, the Mintron time base (and its integration periods) will slowly drift relative to the test pulse. This has allowed me to explore the effects of a target flash occurring at various times relative to the internal Mintron integration timing. While there is no standard method of knowing in real time the timing of the internal integration period, under suitable conditions one can sometimes infer the integration times from step changes in the background signal from the video.

Finally, I note that there are occasional calls for "oscilloscope" monitoring of the Mintron to determine how it works. Oscilloscope monitoring, per se, will not shed light on the behaviors of concern here. Instead, to understand the integration and timing behaviors requires carefully timed and analyzed test signals such as used here.

Discussion

Once the Mintron makes its averaged image and outputs it as video, I could verify that the ensuing fields are identical to within several percent in amplitude. The variations I saw include the recording, playback, digitizing, and analysis noise, as well as any intrinsic to the camera.

One question sometimes raised about the Mintron is whether it includes some form of internal delay in addition to the integration effects, for example, an additional internal delay of one field (1/60 sec). However, this testing showed that there is no such internal delay, either at x1 or any other integration setting.

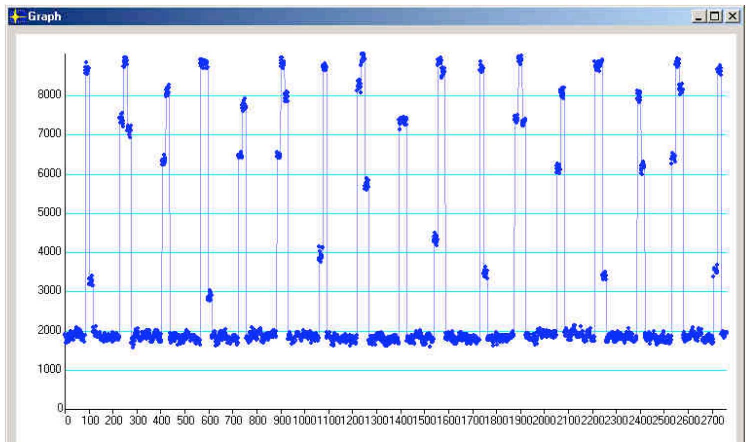
The logic introduces a number of issues concerning timing accuracy. The most obvious effects are the result of the lack of synchronization between an event and the internal timing of the integration periods.

The incoming target flash may be of any duration. Again assuming a x8 operation, if the target signal is one field in duration (1/60 sec), then it will be captured during the integration period. When the integration is finished, the next eight fields will show the target brightness at "full" (averaged) brightness, and the next eight fields will show the target back to zero brightness. Because the target flash may occur at any time relative to the integration period, the start of the flash in the resulting video may be as little as one field period after the actual flash (if the flash occurred during the last field of the integration period) or as many as eight fields later than the actual flash (flash occurred in the first integrating field). That is, the timing of the flash in the video occurs with a random delay of up to 8 fields, i.e. 0-133ms. Note that this is NOT a standard random effect in that it does NOT follow a normal statistical distribution centered around the middle (average) of the delay. While the average delay is 66.5ms, the delay is equally likely anywhere in the range. If combined with more normal statistical delays, this may well affect estimates of uncertainty in the final timing analysis.

The situation is more complex for longer target flashes. This is the more common event in astronomy, where the event might last for perhaps five seconds while the integration may well be x8 or 133ms.

The next longer target flash than 1 field duration is two fields. In this case, the odds that the flash will occur within a single integration period are 3:4. That is, 1/4 of the events will bridge between two integration periods. The result will be two sets of 8 fields (total 16) showing the event, but with half the amplitude of the "normal" event. What was a 1/30 sec=30ms event shows in the video as lasting for 266 ms.

A target flash that is 10 fields in duration will always fill one integration period, and may spill over into either one or two adjacent integration periods, albeit with significantly reduced amplitude.



The Figure shows an LiMovie screen shot in which the Mintron is operating at x32, the target flashed once every five seconds at a flash duration of 30 fields alternating with 60 fields. One can see the complex mix of widths and amplitudes that can result! The LiMovie graph shows frames (each equals two fields).

A target flash much longer than the integration period will usually show a stepped rise/fall depending on just when it comes in. In practice, for astronomical targets, there is usually substantial variation in brightness on this time scale due to scintillation or other effects, which will fold into and mask the effects of bridging the integration periods. However, it is clear that the Kiwi timing of the start (or end) of an event will always be delayed by 1/2 the integration duration, and uncertain by 0-1/2 the integration duration.

There is another effect of these behaviors. If the Mintron in integration mode is used, for example, to observe an asteroid occultation, the observer may see a stepped disappearance and perhaps even a stepped reappearance of the occulted star, and be led to conclude that an asteroid satellite or a double star had been observed. This could be the case, for example, if the timings were similar to that of the second test flash shown in the Figure. However, it is entirely possible that one has only seen an example of the artifact discussed above as the events bridge across adjacent integration periods.

Conclusion

The behavior of the Mintron is reasonably straightforward, so that potential timing errors in integration modes can be properly accounted. This is important whether the Mintron is used either directly (real time video) or in a Drift Scan mode (as suggested by Derek Breit) when observing occultations.