Measurement of the acquisition delay of a digital camera

without SEXTA

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The acquisition delay was defined by D. Gault and H. Pavlov in an article in the Journal for Occultation Astronomy [2]

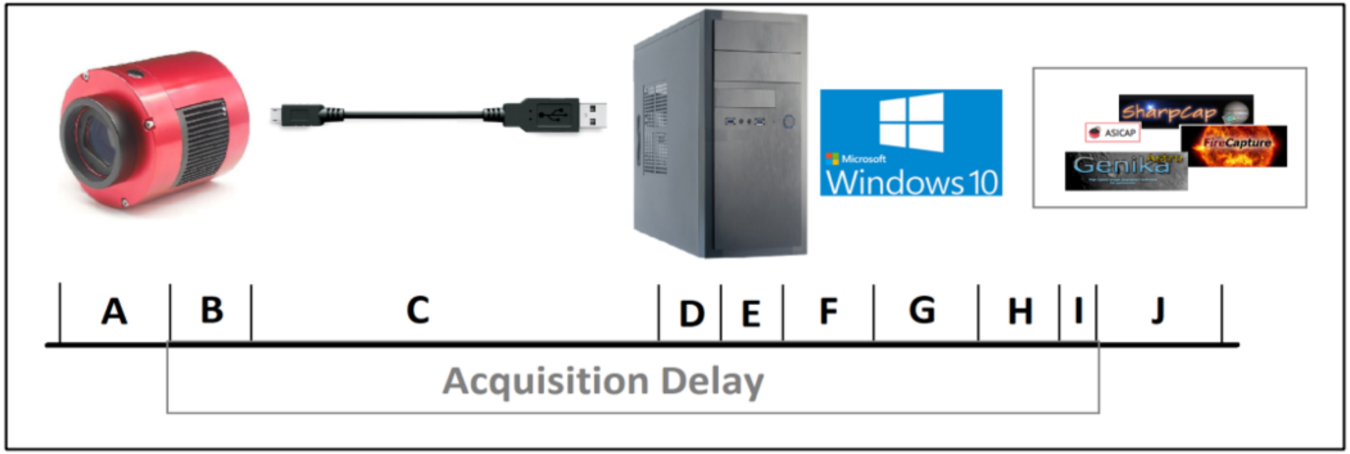


Figure 1. Time delays in a video acquisition system using a PC. The size of the named segments does not correspond to the actual size of the experienced delay in the corresponding named segment.

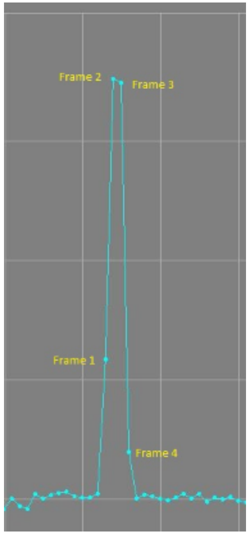
The acquisition delay is the difference in time between
- the date of the end of exposure of an image

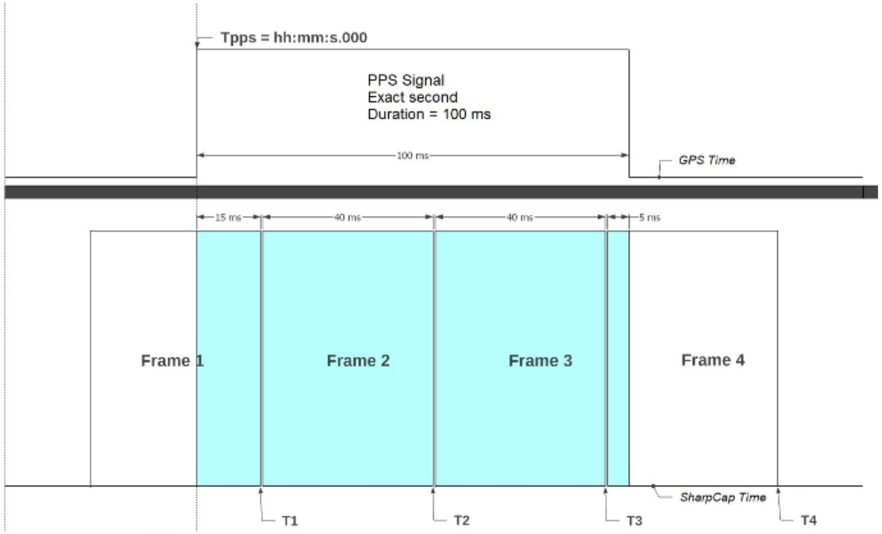
and

- the date when this image is time-stamped by the video acquisition software

Principle

The PPS signal from a GPS module is used to power an LED.
The light flow is recorded with a digital camera and analyzed with Tangra.





T1, T2, T3 and T4 are the end-of-frame time stamps made by the video software.

The blue area corresponds to the fluxes measured by Tangra for each frame.

The 1PPS signal with a duration of 100 ms appears towards the end of frame 1 and lasts 15 ms.

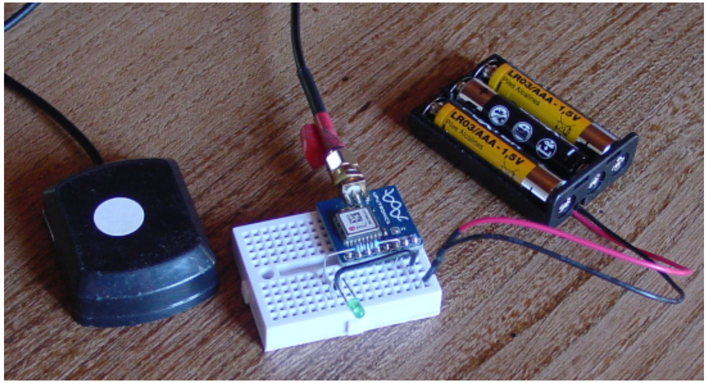
The light intensity of the LED being constant, the flux is proportional to the duration of the 1PPS signal in the four frames.

Total Flux = Flux 1 + Flux 2 + Flux3 + Flux 4
Unit Flux= Total Flux/ 100 ms
PPS1 Duration = Flux1 / Unit Flux

T_end = T_pps + DurationPPS1
T1 = End of exposure timestamp of the Frame1 determined by the acquisition software.

Acquisition Delay = T1 - T_end

The equipment used



- a GPS module with PPS signal
  Uputronics Module uBLOX MAX-M8Q Breakout [3] [4]
- a GPS antenna
- a 3 mm diameter LED
- a protective resistor with a value of 4.7 kΩ to 22 kΩ
- two or three 4.5 V batteries depending on the voltage of the GPS module

Carry out the assembly of the image.
The plus pole of the LED is connected to the TP connection of the GPS module, the minus pole to the GRND.

- digital cameras tested :
  ZWO ASI 174MMC with Global Shutter
  QHY 224C with Rolling Shutter

- a standalone NTP stratum 1 time server based on a Raspberry Pi [5]

- Asus N750J computer : i7+SSD, Windows 10

- a crossed RJ45 cable

The software used

- **Meinberg NTP** software to synchronize the Windows system clock [6].

- **Meinberg NTP Monitor** software to monitor the NTP regulation of the clock [7]

- **SharpCap** version 4.0.8395.0 for video recording [8].

- **Tangra** version 3.7.0.3 for video file reduction [9].

- a **spreadsheet** to exploit the .csv files [10].

Checking the duration of the 1PPS signal

A first way is to use an oscilloscope.

A second is to make a video recording.

With the smallest window possible, record a video of the LED

e.g.: exposure time of 2 ms and duration of 30 s to 1 min.

Make a reduction of the video images with Tangra.

In the .csv file count the number of images in which the 1PPS signal is present.

Deduce the duration of the PPS signal.

Check the regularity of the time stamp of the images concerned.

The Uputronics GPS module used has a 1PPS signal duration of 100 ms.

It is possible to extend the duration of the PPS signal, see Appendix A.

Video recordings

Given the principle used, the PPS signal must be spread over at least two images.

The exposure time must therefore be at most 50 ms.

Protocol

Record 3 videos with SharpCap.

- Parameters
  - Coulour Space = Mono16 or Raw16
  - Ouput Format = FITS files
  - Debayer = Off
  - Frame Rate Limit = Maximum
  - Exposure = between 25 and 50 ms
  - Recording time = about 2000 images.

Perform video reduction with Tangra.

- Parameters used:
  - DATE-END
  - Vertical Flip to straighten the image completely
  - Untracked

Save the light curve in .lc format and in .csv file.

Use .csv file with a spreadsheet

Example of calculations

	A	B	C	D	E	F	G	H	I	J
1	Acquisition Delay of a digital camera									
2										
3								Duration Exposure	40	
4	**FrameNo**	**Time (UT)**	**Signal (1)**	**BackGround (1)**	**SmB (1)**	**PPS**				
5	24	[23:49:17.909]	2 956	3 070	-114			Duration PPS	100	
6	25	[23:49:17.948]	2 914	2 877	37					
7	26	[23:49:17.989]	2 938	2 971	-33			Total Flux	99 337	
8	27	[23:49:18.029]	29 714	2 994	**26 720**	PPS1		Flux 1	26 720	
9	28	[23:49:18.069]	43 203	3 092	**40 111**	PPS2				
10	29	[23:49:18.109]	35 560	3 054	**32 506**	PPS3		Unit Flux (per ms)	993	
11	30	[23:49:18.149]	3 091	3 049	42			PPS1 duration	26,9	Flux 1 / Flux Unitaire
12	31	[23:49:18.189]	2 993	3 130	-137					
13	32	[23:49:18.229]	3 077	2 936	141			Time (UT) PPS1	[23:49:18.029]	
14								Time (UT) PPS1 HH	23	hour part
15								Time (UT) PPS1 MM	49	minute part
16		Time (UT) =middle image timestamp by Tangra						Time (UT) PPS1 SS	18,029	seconde part
17										
18								Time (UT) PPS1 (in secondes)	85 758,029	Conversion in seconds of Time (UT) PPS1
19										
20								T_END (in secondes)	85 758,049	Time (UT) PPS1 + Exposure /2
21										
22								T_PPS	85758,000	Integer part T_END
23										
24								T_fin PPS	85758,027	T_PPS + PPS1 duration
25										
26								Acquisition Delay (ms)	22,1	T_END - T_fin PPS
27										

SmB(1) = Signal(1) - BackGround(1)

The presence of the 1PPS signal is detected by Smb(1) values significantly higher than the base signal

In this example the 1PPS signal appears in frame 27 (PPS1), is present in frames 28 and 29 (PPS2 and PPS3)

For the calculations

The previous spreadsheet is available on the Internet [10].

For the results presented in the rest of this presentation calculations were made using DATE-END from SharpCap.

For each row of results, the values obtained correspond to the average of 3 videos

Results with a Global Shutter ZWO ASI 174MMC camera

Influence of the duration of exposure

Exhibition	Inter Frame (ms)	3 σ	Acquisition delay (ms)	3 σ
25	25,1	1,4	**22,2**	1,0
40	40,1	1,0	**22,3**	1,4

Table 1: Influence of exposure time

Windowing = 1936x1216, Binning 2, Turbo USB = 80
(the values obtained are the average of 3 videos)

Conclusion :

The duration of exposure has no influence on the acquisition delay.

The results are 99.7% within ± 1.5 ms.

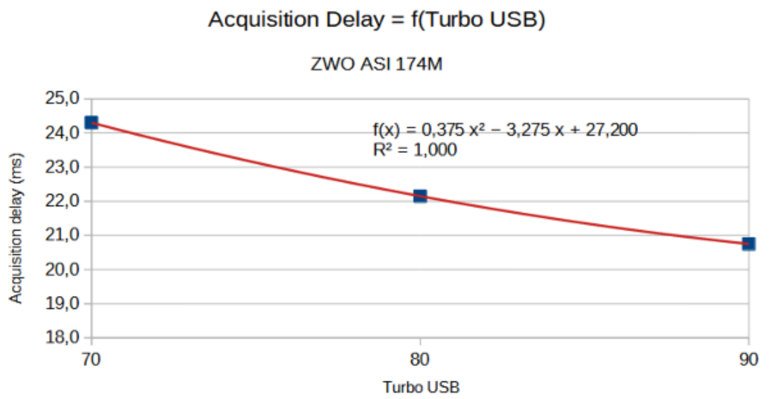
Results with a Global Shutter ZWO ASI 174MMC camera

Influence of the USB speed

Turbo USB	Inter Fr. (ms)	3 σ	Acq. time (ms)	3 σ
70	25,1	1,50	**24,3**	1,00
80	25,1	1,40	**22,2**	0,95
90	25,1	1,65	**20,8**	0,90

Table 2: Influence of the USB speed

Capture area = 1936x1216, binning = 2, Exposure = 25 ms, Gain = 40
(the values obtained are the average of 3 videos)



Conclusion :

The USB transfer speed influences the acquisition time.

The results are 99.7% within ± 1 ms.

Case of Rolling Shutter cameras

In a Global Shutter camera **all pixels** in an image **have the same time stamp**.

In the case of a Rolling Shutter camera, the lines of the sensor are read successively.

Only pixels in the same row have the same timestamp.

The method described above remains valid when **applied to a line of pixels**.

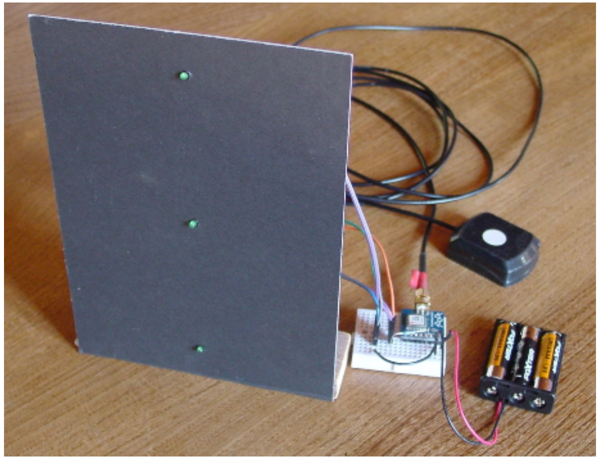


Figure 3: Three LED system for Rolling Shutter camera

For this type of camera, the single LED device has been modified by using **three LEDs** powered in parallel.

For video recording:

- LEDs are placed vertically
- the middle LED has been placed in the center of the sensor

In Tangra the selection of the three LEDs was made in the direction from top to bottom.

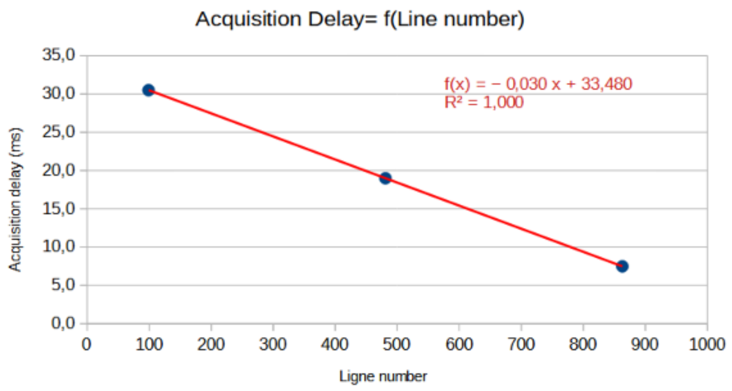
The origin (0, 0) of the Tangra coordinate system is at the top left.

Results with a Rolling Shutter QHY224C camera

Influence of the duration of exposure

Exposure (ms)	Inter F. (ms)	3 σ	LED1 Y	Delay_1 (ms)	3 σ_1	LED2 Y	Delay_2 (ms)	3 σ_2	LED3 Y	Delay_3 (ms)	3 σ_3
30	30,0	1,8	99	**30,6**	2,04	481	**19,1**	1,89	863	**7,53**	1,84
40	40,0	2,1	99	**30,6**	2,24	481	**19,0**	2,11	863	**7,49**	2,13
50	50,0	1,9	99	**30,5**	2,06	481	**19,0**	2,03	863	**7,51**	2,16

Table 4: Influence of exposure time
Capture area = 1280x960, Binning = 1X1, USB Traffic = 0 (the values obtained are the average of 3 videos)



After the last line is read, there is a residual acquisition time corresponding to the transfer and post-processing of the image by the driver and SharpCap

Approximately 5 ms in the case of the QHY224C.

The simple line correction by the usual formula is therefore only approximate.

Conclusion :

Acquisition delay :

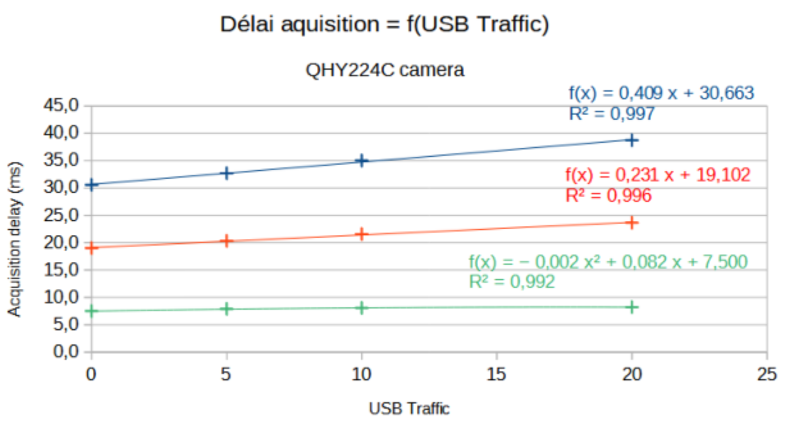
- **does not depend of exposure duration for the same sensor line**
- **depends on the sensor line where the LED (or star) is located.**

Results with a Rolling Shutter QHY224C camera

Influence of the USB speed (USB Traffic)

USB Traffic	Inter F. (ms)	3 σ	LED1 Y	Delay_1 (ms)	3 σ_1	LED2 Y	Delay_2 (ms)	3 σ_2	LED3 Y	Delay_3 (ms)	3 σ_3
0	40,0	2,1	99	**30,6**	2,24	481	**19,0**	2,11	863	**7,5**	2,13
5	40,0	1,8	99	**32,7**	2,01	481	**20,3**	2,17	863	**7,9**	2,06
10	40,0	1,9	99	**35,0**	2,09	481	**21,6**	2,12	863	**8,1**	2,20
20	40,0	1,8	99	**38,7**	3,18	481	**23,6**	2,31	863	**8,2**	2,69

Table 5: Influence of USB Traffic
Capture area = 1280x960, Binning = 1x1, Expo = 40 ms (the values obtained correspond to the average of 3 videos)



Conclusion :

The acquisition time depends on :

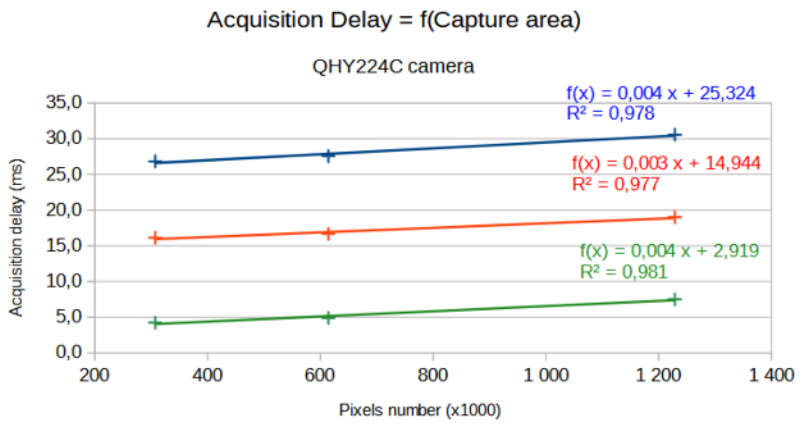
- **of the USB transmission speed**
- **of the sensor line on which the LED (or star) is located.**

Results with a Rolling Shutter QHY224C camera

Influence of capture area

Capture area	Inter Fr. (ms)	3 σ	LED1 Y	Delay_1 (ms)	3 σ_1	LED2 Y	Delay_2 (ms)	3 σ_2	LED3 Y	Delay_3 (ms)	3 σ_3
1280x960	40,0	2,09	99	**30,6**	2,24	481	**19,0**	2,11	863	**7,5**	2,13
640x960	40,0	2,56	99	**27,6**	5,15	481	**16,7**	2,59	863	**4,9**	3,54
320x960	40,0	3,04	99	**26,8**	4,98	481	**16,1**	2,49	863	**4,2**	3,12

Table 6: Influence of capture area
Binning = 1x1, Expo = 40 ms, USB Traffic = 0, Gain = 10 (the values obtained correspond to the average of 3 videos)



Conclusion :

The acquisition time depends on:

- **of the capture area,**
  thus the number of pixels transmitted by the USB link

- **of the sensor line on which the LED (or star) is located**

Conclusions

Factor	Influence
Exposure	NO
Gain	NO
Capture area	YES
USB speed	YES
Binning	YES

To simplify your life, a good solution:

- Adopt only one or two sets of parameters (capture area, binning, USB speed).
- Measure and apply the corresponding acquisition delay.

For a Rolling Shutter camera, it is necessary to position the LED (or star) :

- **always on the same line of the sensor**,
- the easiest way is to **center it on the sensor**.

It is not necessary to know the direction of the scan with the method used.

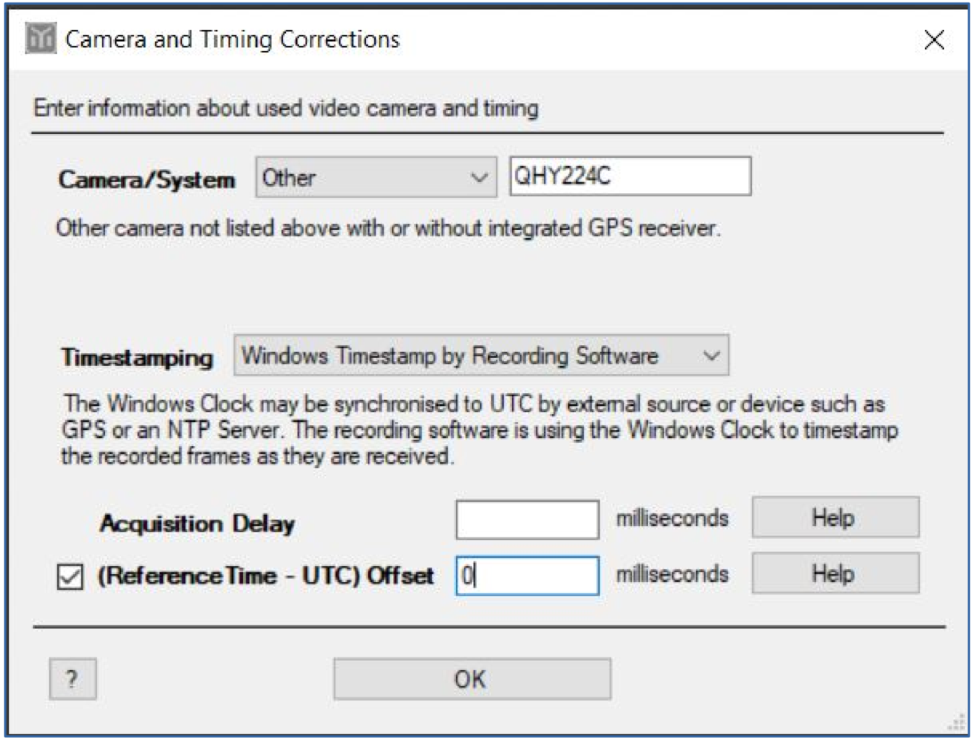
For any change**, software or hardware,** in the acquisition chain**:**

- **it should be verified that the value of the acquisition delay has not been changed.**

Final conclusion

The described method allows to measure the acquisition delay of a digital camera to ± 2 ms at 99.7 %.

All that remains is to fill out the Tangra form.



Appendix A

Modification of the duration of the PPS signal

The duration of the PPS signal can be extended by using a monostable integrated circuit like CD4538 or equivalent.
The principle of assembly can be easily found on the Internet, for example [11].

This adaptation was performed in 2016 for the OST time-stamping system [12] with a CD14538BE circuit from Texas Instruments bought at Conrad.
With a 100 kΩ resistor and a 4,7 μF capacitor the theoretical duration is 470 ms for a real value of 464 ms.
The actual value depends on the tolerance of the components, so it must be measured.

At the time of writing, the CD14538BE no longer appears to be available from Conrad.
You will have to search on the Internet with 'CD4538' to find an equivalent circuit and/or another supplier.

Some GPS modules have a USB plug (like HAT GPS card in version 6.3 from Uputronics) it is then possible to use the U-Center software from Ublox to make this modification. In the absence of this USB plug you have to build a serial connection with a DB9 plug and a serial to USB converter cable.

Bibliography

[1] contact : plc (at) nocturno.fr ; website : http://www.nocturno.fr/

[2] Pavlov, H., Gault, D. Using the Windows Clock with Network Time Protocol (NTP) for Occultation Timing. Journal for Occultation Astronomy, Volume 10 - No. 2- 2020-2.

[3] GPS module: https://store.uputronics.com/index.php?route=product/product&path=64&product_id=84

[4] The GPS module available at Kubii :
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[5] Le Cam P., Marquette J.B., Realization and validation of a stratum 1 time server in autonomous mode, Sociéte Astronomique de France, Ecole de Photométrie 2022 à Besançon.

[6] Meinberg NTP software:
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[8] SharpCap:
https://www.sharpcap.co.uk/sharpcap/downloads

[9] Tangra:
http://www.hristopavlov.net/Tangra3/

[10] Sample calculation files:
http://www.nocturno.fr/scripting/acqd.html

[11] Monostables: https://www.sonelec-musique.com/electronique_bases_monostables.html

[12] OST: http://www.nocturno.fr/ost/ost.html and http://www.nocturno.fr/ost/electronique.html