Standard modes of MPIA's current H2/H2RG-readout systems

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ABSTRACT

Even though the last instruments built with the previous generation of MPIA-ROE are offering in the meantime most of the standard readout modes, the current generation ROE is based on the experience of the last years, and besides other properties like small volume, more channels, less power consumption, etc., it will also allow extended readout modes in the near future by using the detector engineering and data interfaces of GEIRS.

The Hawaii-2-RG detector has a large amount of operational flexibilities to support extended readout modes. With special properties in the pattern generator of the ROE and in GEIRS, new extended readout modes can be implemented identically for the Hawaii-2 and the Hawaii-2RG in multichannel mode.

This paper presents an overview of the standard readout schemes and describes additional selectable options, offered idle-modes, and some new extended modes available with this generation of MPIA-ROE for the next instruments and instrument updates using HgCdTe-detectors.

During the last 15 years MPIA has built 8 sets of previous readout electronics (ROE) for 8 astronomical infrared instruments[1-8]. The generic infrared camera software GEIRS (spoken like 'cheers') is used in these instruments either as a pure readout software layer or as an overall control software for IR-instruments, the last case in particular with instruments for the Calar-Alto observatory in Spain.

Keywords: HAWAII.-2, HAWAII-2RG, infrared, NIR, readout.

1. INTRODUCTION

The described standard readout modes are a basic set of clocking pattern logic, applicable identically either to the previous HAWAII-2 detector generation or the actual HAWAII-2RG, both using the current ROE of MPIA. Therefore these patterns are based on the line-reset, which is the only available reset type of the HAWAII-2.

This is not a limitation to the HAWAII-2RG. For fast readout of the full frame size the multi channel detector mode is preferred, which is also supported by the full frame and the multi window readout of the MPIA standard modes.

We use the single frame time **R** as time unit, which is valid for any clocking speed, any pattern options like pixel multisampling and any multi window frame size.

The time formula of readout modes are done in a way to allow easy check for the observation preparation: Based on the single image read integration time (**DIT**), the count **N** of cycle repeat done in a single ROE read command, the correlation count **multi** and, to hold the result exact also for the li-modes, in the time **lrdtime** needed to clock a single channel line.

We try to describe the pros and cons of the different readout modes, some advanced readout clocking modes possible with the current MPIA readout electronics (ROE), and experiences related the readout schemes used with the HAWAII-2 detectors, that we had tested for the different instruments.

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2. RESET AND FRAME SCHEMES

The presented readout modes are different solutions to embed the line-reset into the pixel clocking pattern and to combine these reset-schemes with a count of correlated nondestructive reads.

Pixel readout clocking of the **Integrate-While-Read-type** of the HAWAII detectors is nondestructive. The pixel cell is always collecting photons. Only if a reset signal is applied to a pixel cell, the current state of this pixel cell is reset, and no photons are collected in this pixel cell as long as the reset-signal applies.

The HAWAII-2 offers only a **line-reset capability** as reset possibility. But together with its nondestructive pixel readout, it is a good chance to get the optimal efficiency of detector integration time also for fast readout at small integration times, because the duration of a line-reset is in the range of microseconds.

Let us have a look at the different embedding positions of the line-reset in the double correlated readout modes, which are using the typical clocking logic of a readout cycle:

Reset – read [– wait additional time] – read.

The image as result of a double correlated readout mode is always the subtraction of the first read out frame from the second read out frame, removing the static, reset-related properties of the detector.

A frame or frame-clocking is the pattern to read once each wanted pixel of the detector. To read a pixel position, it has first to be addressed via the fast and slow scanner registers. These 2 registers on HAWAI-2 are only able to be cleared or incremented.

2.1 Line-reset in front of line-clocking (e.g. rrr-mpia)

The **single frame read R** is done by clearing the slow scanner and executing for each line a pattern, which increments the slow scanner, clears the fast scanner, resets the line (or not), and clocks all pixels of the line by incrementing the fast scanner.

The 2^{nd} read out frame has instead of the real line-reset part only a dummy No-line-reset pattern, to get for all pixels of the resulting image identical integration times.

In multi-channel mode of the detector, e.g. 32-channels, this is done simultaneous in all 32 channels.

2.2 Line-reset between dual line-clocking of the same line (e.g. full-mpia)

The **interleaved dual frame read 2R** executes after clearing of the slow scanner for each line a pattern, which increments the slow scanner, clocks all pixels of the line by incrementing the fast scanner, clears the fast scanner a 2^{nd} time, resets the line (or not), and clocks a 2^{nd} time all pixels of the line by incrementing the fast scanner.

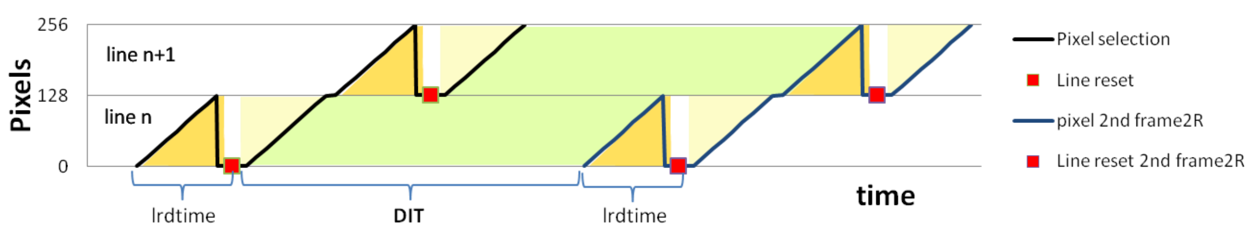


Figure 1 shows 2 lines of a single full-mpia/lir readout cycle, which clocks with the time distance DIT two times the interleaved dual frame read 2R. In each 2R-scheme, each line is clocked immediately two times. If the end of the first line-clocking is reached, the fast pixel scanner is cleared once again, the line reset applied, and then the same line clocked a second time, before doing the same in the next line. For a short time after the line reset, all pixels of the line are collecting light (light yellow or light grey area) until these pixels are clocked again. Now the light (green or middle grey) collected contributes to the DIT, until the same line is clocked again in the 2^{nd} interleaved dual frame read 2R. The rest of the collected light (orange or dark grey area) during a single **lrdtime** (line read time) until the 2^{nd} line reset is applied, is no more contributing to the DIT-part. As long as this full-mpia or lir readout cycle is repeated the efficiency of a cycle is *DIT/(DIT+lrdtime)*, where lrdtime is the frame time R divided by line-count-to-read, or R/2048 for a full frame readout of an HAWAII-2RG, resulting in a cycle repeat efficiency better than 0.999.

This interleaved dual frame logic reads 2 frames, always one frame of two sequential readout cycles. By repeating this dual frame clocking, the lines read before the line-resets belong to the 2nd read out frame of the previous readout cycle, containing the photon collection information, and the lines read behind the line-resets are the 1st read out frame of the next readout cycle.

The **full-mpia** readout mode was introduced 1997/98 with OmegaCass[1] using an HAWAII-1 detector. Since Omega2000[4] the full-mpia mode is also called **lir,** line interlaced read.

In Figure 1, two lines zoomed out of the full-mpia/lir readout pattern scheme of chapter 4.3 are shown, to get an idea of the principle of the interleaved dual frame read 2R.

2.3 Line-reset behind the line-clocking (e.g. half-mpia)

Here the **single frame read R** is done by clearing the slow scanner and executing for each line a pattern, which increments the slow scanner, clears the fast scanner, clocks all pixels of the line by incrementing the fast scanner, and then resets the line (or not).

Here the 1st read out frame has instead of the real line-reset part only a dummy No-line-reset pattern, to get for all pixels of the resulting image identical integration times, and the 2nd read out frame, which includes the photon collection information, contains the line-resets. The 2 frames belong here to the same cycle, but the reset is always the related reset of the next cycle.

This half-mpia single frame read R is very similar to the rrr-mpia frame read, only the reset of the line is moved to the end of the line read. Therefore the half-mpia mode is also called fecr, fast-end-of-line correlated read.

2.4 Fast frame reset (by line-resets)

The fastest possibility to reset the full HAWAII-2 detector is to clear the slow scanner and execute for each line a pattern, which increments the slow scanner, clears the fast scanner and resets the line. This takes for the 1024 or 2048 lines of the detectors about 2 to 10 milliseconds (depending on the length of the applied reset-signals).

This fast-frame-reset is used in the **o2dcr** mode, introduced with Omega2000 detector tests[4]. After resetting the detector with the fast frame reset, 2 additional single frames (without embedded line-resets) are read according to the above given double correlated readout cycle logic.

(The HAWAII-2RG offers here additionally the Global Reset, a much faster solution.)

2.5 Frame reset (by line-resets)

The frame reset is used to simulate the earlier NICMOS reset type, which was clocking always a full frame time R for resetting and stabilizing the detector behavior.

This means a double correlated readout **rrr** cycle consists always of 3 times of clocking a frame R, where the first frame contains the embedded line-resets and the pixel-clocking is not converted via ADCs to data, but the 2nd and 3rd frames (without embedded line-resets) are read out according to the double correlated readout cycle logic.

The frame reset, which is used also as short idle-clocking mode, is either of type *single frame read R* with embedded line-resets before or after the line clocking, or of type *interleaved dual frame read 2R* with embedded line-resets, depending on the readout mode applied.

(The HAWAII-2RG offers here additionally the Pixel Reset, which may be applied to any single pixel.)

3. OVERVIEW

In Table 1 an overview of the characteristics of the MPIA standard readout modes is given.

The **dynamic range** or **integration range** of the photon collecting pixel cells of the detector decides about the time of saturation at brighter sources. The different readout modes are mainly limiting this range if used at minimal DIT time (minDIT), in which the photon collection times before the DIT and after the DIT are contributing in the largest ratio given by the special readout schemes.

The photon collection by the detector between the last frame read of a cycle and the reset of the next cycle is normally hidden from the incoming data result. We call this the **integration overflow**. To protect against the integration overflow we use an optional embedded additional reset at the end of the lines of the last frame read in the relevant readout modes.

Table 1 lists the standard readout modes of the MPIA readout system and its basic characteristics. (R=Read-time of a single frame, 2R=Read-time of an interlaced dual frame; multi=correlation-count ≥2; o2t=additional time needed for the fast-frame-reset and optional the additional preclocking of some lines; lrdtime=time to read a single line. Only in the modes using the fast-frame-reset are the pixels values coming from different dynamic ranges).

Readout mode	*Frames-to-reset correlation*	*Reset type*	*Detector-I-efficiency per cycle*	*minDIT*	*Integration range at minDIT*	*Detector time needed for N cycles*	*I-overflow wo/w protection*
sfr	*no*	(idle-type)	0.0 - 1.0	≤R (idle-type)	~0.0 - 1.0 (idle-type)	N*DIT	R / -
rr-mpia	*single*	frame	≥0.5	R	1.0	N(DIT+R)	R / 0
Rlr	*single*	line	~0.0	~0	1.0	N*R	R / 0
o2scr	*single*	fast-frame	0.0 - ~ 1.0 (line dep.)	≤R (line dep.)	~0.0 – 1.0 (line dep.)	N(DIT+R+o2time)	≤R (line dep.)
rrr-mpia [fcr]	*double*	line	≥0.5	R	1.0	N(DIT+R)	R / 0
full-mpia [**lir**]	*double*	line	N=1: >0.5 N>1: ~1.0	(2R-lrdtime)	1.0	N(DIT+lrdtime)+2R	0
half-mpia [fecr]	*double*	line	N=1: >0.33 N>1: >0.5	R	0.5	N(DIT+R)+R	0
rrr	*double*	frame	≥0.33	R	0.5	N(DIT+2*R)	R / 0
o2dcr	*double*	fast-frame	≥0.5	R	~0.5 – 1.0 (line dep.)	N(DIT+R+o2time)	≤R / 0 (line dep.)
mer [fowler]	*multi (2,4,6,8,..)*	line	≥0.5	(multi/2)R	1.0	N(DIT+R(multi/2))	R / 0
srr	*multi (2,3,..)*	line	≥0.5	(multi-1)R	1.0	N(DIT+R)	R / 0
msr	*multi (2,3,..)*	line	≥0.5	R *[(multi-1)*R]*	1.0/(multi-1)	N(DIT*(multi-1) +R)	R / 0
cntsr	*multi (2,3,..)*	line	≥0.5	(multi-1)R	1.0	N(multi*R) [≡ N(DIT+R)]	R / 0
limer [li-fowler]	*multi (2,4+2,8+2,..)*	line	>0.5	((multi+2)/4)* 2R -lrdtime	1.0	N(DIT+lrdtime+ 2R((multi+2)/4-1))+2R	0
lisrr	*multi (2,4,6,8,..)*	line	N=1: >0.5 N>1: ~1.0	(multi/2)*2R -lrdtime	1.0	N(DIT+lrdtime)+2R	0
limsr	*multi (2,4,6,8,..)*	line	N=1: >0.5 N>1: ~1.0	(2R-lrdtime) *[..*multi/2]*	1.0/(multi/2)	N((DIT+lrdtime)* multi/2)+2R	0
licntsr	*multi (2,4,6,8,..)*	line	N=1: >0.5 N>1: ~1.0	(multi/2)*2R -lrdtime	1.0	N(multi/2*2R)+2R [≡N(DIT+lrdtime)+2R]	0

3.1 Integration efficiency

The time of an observation at the telescope is depending directly on the integration efficiency of a readout mode, the ratio of the wanted exposure time of an object versus the needed detector clocking time. In the readout mode pattern schemes one can see that each readout mode has more or less parts with photon collection times, which does not contribute to the sum of DITs of an exposure (green or middle-grey areas).

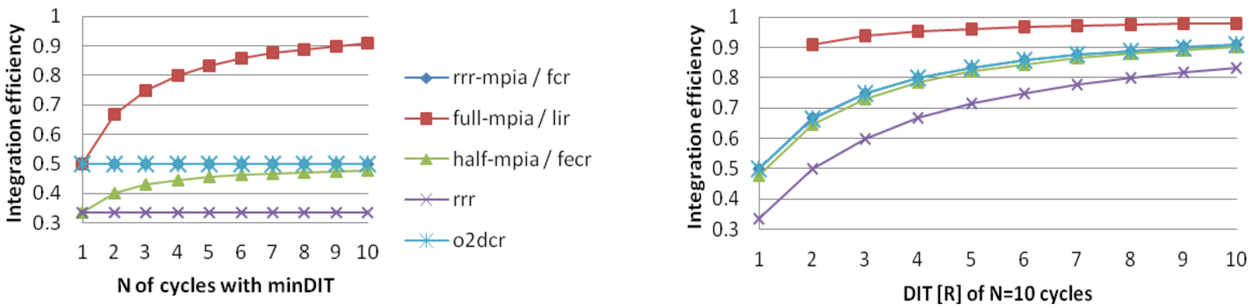


Figure 2: Integration efficiency of the double correlated readout modes, as exposure time (N*DIT) divided by the needed detector clocking time: On the left side drawn with minimal DIT versus number N of repeated cycles, on the right side drawn with N=10 versus DIT in units of the single frame read time R.

All multi correlated readout modes using multi count 2 behave like the corresponding double correlated readout modes using the same reset scheme: mer, srr, cntsr, and msr behave like rrr-mpia/fcr; and multi li-modes like lir/fullmpia. This also helps to verify the multi correlated readout patterns.

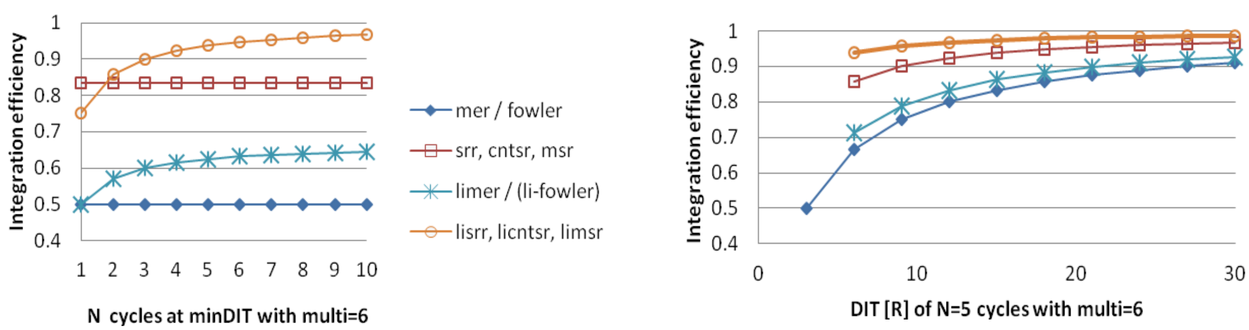


Figure 3: Integration efficiency of the multi correlated readout modes with correlation count multi=6, as exposure time (N*DIT) divided by the needed detector clocking time: On the left side drawn with minimal DIT versus number N of repeated cycles, on the right side drawn with N=5 versus DIT in units of the single frame read time R.

3.2 Why so many readout modes?

Optimization of integration efficiency to reduce telescope observation time, different instrument limitations by the observation (read-noise, background, etc.), and different behaviors of different detector builds/series are good reasons to test the detector behavior in different directions and to select the best compromise for the instrument.

4. THE STANDARD READOUT MODES

At initialization time all full frame standard-readout patterns are loaded. This allows fast switching between different readout modes and idle types. Pattern modifications are only needed to load, if some options like pixelclock or other timings, or like the pixel multisampling count are changed.

Sharing of subpattern parts guarantees identical timing-behavior in all frames of idle-types and readout modes; it also reduces redundancy effects, when a pattern-part has to be modified.

The symbolized readout schemes consist mainly on the following parts. A single black line ramp symbolizes the clocking and readout of one frame of all wanted lines and pixels. Two parallel-in-time drawn dark lines represent the interlaced dual frame clocking. A middle grey dotted line is also a clocking of one frame, but without readout of data. The red (middle dark) dashed line shows a reset, either embedded in the parallel-in-time drawn frame(s)-clocking, or just as a fast frame reset.

The schemes show always two consecutive executed readout cycles. A single started readout is normally repeated for N cycles by the pattern generator to collect N*DIT integrated single readout images, the so called exposure and exposure time.

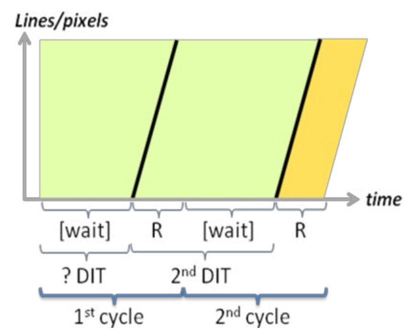
The length of the DIT is always shown at the first line position in the ramp of the nondestructive readout, where the photons collection time for each pixel is always delayed a little with the sequential pixel clocking time.

If the optional [wait] time is removed or set to zero, the minimal DIT and cycle time is reached. For readout modes, where the last or the first cycle needs an additional frame-clocking, like the li-modes, the longer cycle time is shown for the first cycle, which is also valid if only a single cycle (N=1) is read out. The times R and 2R, and also lrdtime and o2time, are explained in the above chapters.

The yellow (light grey), green (middle grey), and orange (darker grey) areas show the times of light collecting before, during, and after the resulting DIT, the single data image integration time (see also Figure 1).

4.1 Not correlated

sfr, single frame read, is just an optional waiting time in front of a single frame read R.



It contains no reset at all, and will saturate the detector for larger N. This mode helps to find the visible light sensitive range of a MUX for instrument tests.

At the end of any N cycle repeats, the pattern is automatical switching seamlessly to the currently selected idle type. Depending on these idle types, the starting reset behavior is defined. For example: A single cycle with idle-type FASTRESET behaves identical to a single o2dcr readout, but N cycles with this cycle type behave like an o2msr-(N+1) readout mode, which is not a MPIA standard mode (see below the msr readout mode).

4.2 Single correlated

Single correlated images contain always all static offsets and characteristics of pixels, channels and detector. They are basically a reset and a single frame read R with an optional additional waiting time in front of that frame.

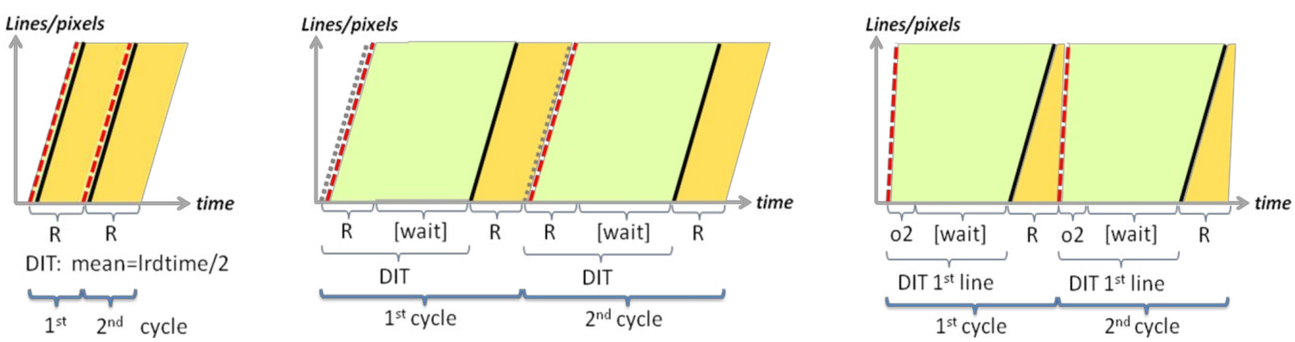


Figure 4: The left readout scheme shows the **rlr**, the middle scheme the **rr-mpia**, and the right the **o2scr** readout scheme.

rlr, reset level read, is based on the fast line reset, and is the readout mode with the shortest integration time DIT. In principle DIT is zero, but it is the time distance between the line reset in front of the line pixels and therefore zero for the first and about lrdtime for the last pixel in the line.

rr-mpia, reset read, is based on the frame reset, which needs the frame time R, and adds an optional wait time before the single frame read. It shows for each pixel nearly the same DIT, but with the variation of the lrdtime, like described in the rlr.

o2scr, o2 single correlated read, uses the fast frame reset and optional wait time before the single frame read. It results in increasing DIT values per line, additionally to the lrdtime variation inside of the line pixels.

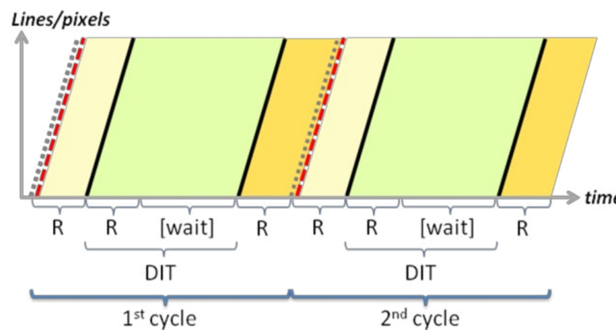
4.3 Double correlated

Double correlated images are always the difference of 2 frames which removes the static detector characteristics, and contain the collected light of time DIT as data result.

rrr, reset read read, is based on the frame oriented reset, which clocks once through all frame pixels (see chapter 2.5). It is similar to the previous NICMOS rrr scheme.

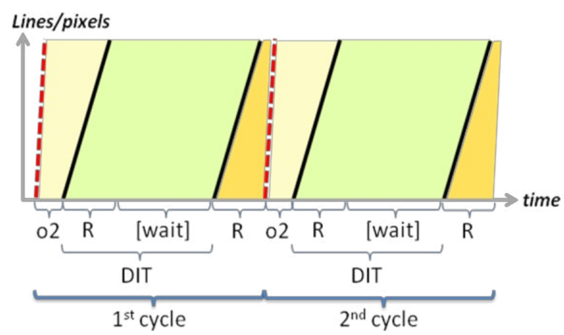
At minimal DIT it reaches only a detector integration efficiency of 1/3 of the detector clocking time.

The frame oriented reset stabilizes the readout behavior of the detector.



o2dcr, o2 double correlated read, is based on the fast frame reset, which resets the frame in a fast line loop (see chapter 2.4). It is a hybrid: the first lines are clocked similar to the rrr-mpia/fcr readout and the last lines similar to the fecr readout. It was used as test mode for different Omega2000 detector problems[4] with different options, but was also selected as main double correlated readout mode for the first Lucifer detector by the commissioning team. This detector had no temporal voltage drift behaviour.

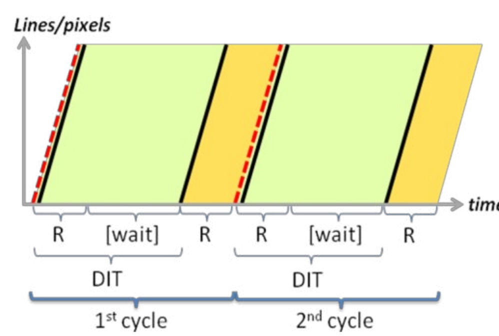
But o2dcr has a drawback: If it is used with small DIT and full dynamic range, the data of the later clocked frame lines derive from higher dynamic detector ranges.



rrr-mpia, reset-read read of mpia, or **fcr**, fast correlated read, is based on the fast line reset and the single frame read R (see chapter 2.1).

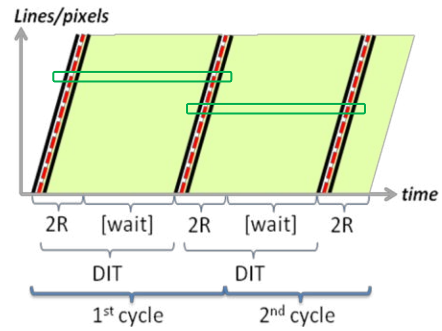
Its main advantage is the full dynamic range for the DIT already at minimal integration time. The first frame contains exactly the same reset level values as in the rlr, reset level read.

With a fitting idle type in front of this readout mode, it is normally the second choice after the full-mpia/lir mode.



The entrapment at minDIT=R of this readout mode is the same overflow time R (orange or darker grey area) after the DIT. When you get values of about the full dynamic range in the resulting image, you may not remark, that the detector will be saturated with about 2*DIT, means the light reaches before the next reset 200 percent of the dynamic detector range. This might result in the next cycle in much higher reset level values in the first frame read if the detector already reaches at this level and time distance persistence effects. You may verify this effect against the fecr, the fast end-of-line-reset correlated read. This persistence effect may appear at minDIT with bright sources in all readout modes, which show after each cycle the orange overflow time R (see also the overflow protection option).

full-mpia, or **lir**, line interlaced read, uses the line reset embedded in the line interlaced dual frame read 2R (see chapter 2.2) and behaves according Figure 1, which is the zoomed scheme of the darker green marked rectangular areas.

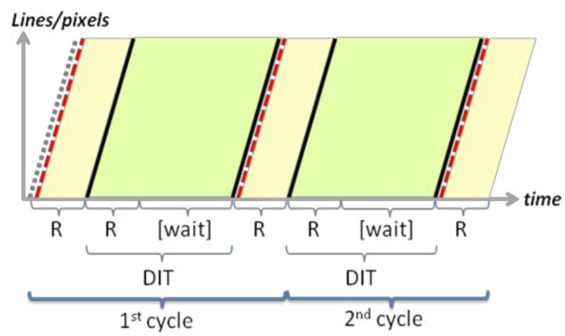


At N cycles repeats, it always has best integration efficieny, full dynamic range, and no photon overflow after DIT. It stabilizes the most detectors against voltage drifts because of its pixel clocking around the reset.

Its small disadvantage is the doubled minimal DIT of 2R compared to modes using only the single frame read R. If possible, try it as windowing mode in that case.

By historical reasons the data acquisition skips in the li-modes always the first frame of the first 2R and the last frame of the last 2R, which are read out, but do not belong to the read cycles.

half-mpia, or **fecr**, fast end-of-line correlated read, is based on the fast line reset at the end of line clocking (see chapter 2.3).



It is a little tricky, because the reset belongs always to the next cycle. Therefore it needs a frame reset with line-resets at the end of line as starting point, like the ECR idle type.

It is similar to the rrr readout mode, but from the 2nd cycle repeat on it has a 50 percent shorter minimal cycle time than the rrr.

And it does not have a hidden overflow time area, because the end-of-line resets behave like an overflow protection.

4.4 Multi correlated

The correlation count **multi** specifies in the next readout modes the count of single frame reads R done to a related reset.

The **mer**, multiple endpoint read mode, better known as fowler mode, is reading the first half of multi count single frames directly after the reset and the second half after the DIT end. The resulting image is the mean of the multi/2 double correlated images, the single fowler pair images, delivering all the same DIT value. Therefore the resulting photon flux is always multi/2*R in time smaller than the needed photon collection time to acquire the data. But it ensures good read noise suppression for smaller multi counts.

The **srr**, sample up the ramp read mode, is distributing the multi single frames read evenly over the DIT time of the readout mode and the resulting image is a pixel by pixel fit of the single frames. For large counts of multi frames filling the ramp without gaps like the cntsr readout variation, the result should be as good or a little better in the suppression of the read noise than for the mer readout, and the resulting total photon flux of srr stays identical with the needed photon collection time. It can also help to remove cosmics immediately.

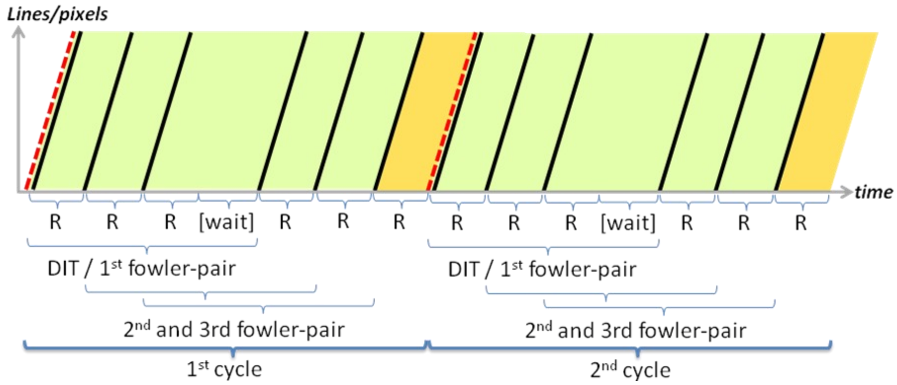
The multi li-modes are built identical, but with the interlaced dual frame read 2R instead of the single frame read R. The lisrr/licntsr need, if all multi correlated readout frames are used, an adapted fitting algorithm compared to the normal srr.

The **msr**, multi sample read, is using the identical srr readout pattern, but produces for each photon collection time between the multi single frame reads a single double correlated image, (multi-1) images per cycle. These msr or also the limsr images might later be checked for nonlinearity of the ramp reads, be corrected for cosmics which appeared during the ramp sampling time, and be fitted as a sample up the ramp image result.

mer-6

mer, multiple endpoint read, also known as **fowler** readout mode, is based on the fast line reset of the single frame read R.

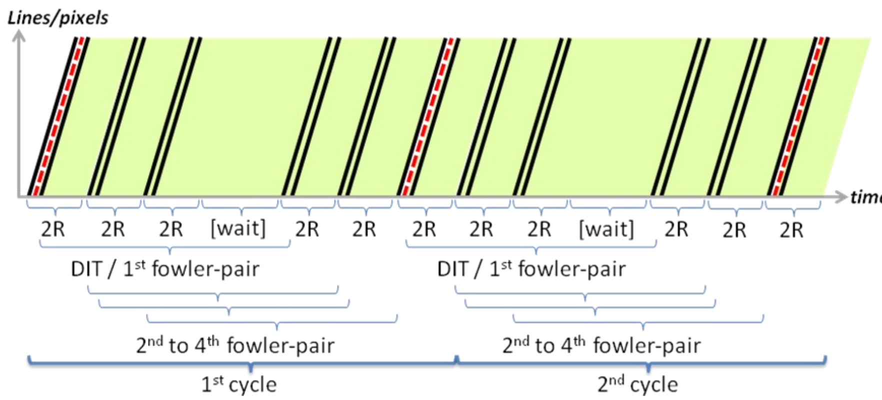
Its orange (darker grey) time R of the overflow area might only get problems at very small correlation counts of 2 and perhaps 4.



limer-(8+2)

limer, line interlaced multiple end-point read, is based on the interlaced dual frame read 2R.

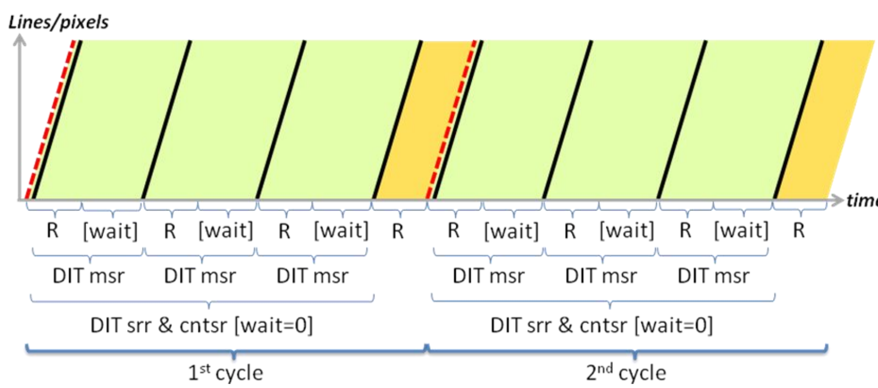
By historical reasons, the 2 samplings around the waiting option are read by the data acquisition, but cannot be used, because the fowler pairs need exact identical DITs.



srr-4, cntsr-4, msr-4

srr, sample up the ramp read, and

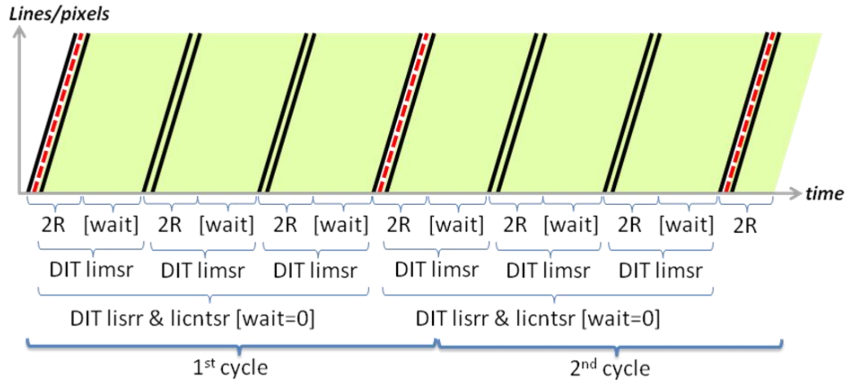
cntsr are both based on the fast line reset of the single frame read R. In contrast to the srr, the cntsr allows only a multiple count of the single frame read time R, but no optional waiting time between the Rs. Therefore a wanted DIT of cntsr is always rounded to the nearest multiple of the Rs.



msr, multi sample read, uses exact the same pattern scheme like the srr, but results in (multi-1) double correlated images.

Its orange (darker grey) time R of the overflow area might only get problems at very small correlation counts of 2 and perhaps 4.

lisrr-8, licntsr-8, limsr-8



lisrr, line interlaced sample up the ramp read, and

licntsr, line interlaced continuous sample read, are both based on the interlaced dual frame read 2R. In contrast to the lisrr, the licntsr allows only a multiple count of the interlaced dual frame read time 2R, but no optional waiting time between the 2Rs. Therefore a wanted DIT of licntsr is always rounded to the nearest multiple of the 2Rs.

limsr, line interlaced multi sample read, uses exactly the same pattern scheme like the lisrr, but results in (multi/2-1) double correlated images.

5. IDLE MODES AND TYPES

Even if the detector is not read out, it has to be ensured, that the detector is not saturating by incoming light. Persistence effects on the detector can take multiple minutes to disappear. Therefore a clocking pattern, which prevents strong detector response, and which delivers no strange artifacts in the first frames at next readout start, has to be started immediately after the last readout, and has to be corrected if a wanted next readout characteristic is modified.

5.1 Idle mode wait, break, and auto

These idle modes control the behavior of the pattern generator at next read start for the transition from idle- to readout-clocking:

Idle-wait	current idle pattern runs until its completion and the readout is started seamlessly.
Idle-break	current idle pattern is stopped and the readout is started immediately.
Idle-auto	if next wanted integration time is below or above a given threshold time, the transition behaves as idle-wait or idle-break.

5.2 Idle types

In the best case, the dynamic state of the detector clocking is not changing (disrupted) at readout start. This implies to use exactly the same readout pattern with the same cycle and integration time as idle-clocking pattern. This idle type **ReadWoConv** is taking always the currently selected readout mode with the same integration time for the idle pattern.

But for long integration times like in multi correlated reads, the usage of the idle-break mode has often a negative effect on the first readout frame, which also depends at which state of the idle-pattern the break appeared.

To be able to minimize the waiting time of the idle-wait transition and to hold the detector in a most similar clocking-and reset-timing of the next readout mode, the 4 different reset-embedded frame patterns also belong to the idle types:

If one of the reset-embedding frame patterns is selected as idle clocking type according to the current readout mode, e.g. the LIR idle type for the full-mpia/lir readout, and repeated until the start of the next readout, in the most cases it delivers, by using the idle-wait mode transition, at least the second best behavior of the detector.

Table 2: Overview of the basic idle types offered with the standard modes of the MPIA readout system.

ReadWoConv	Uses the current selected readout mode with identical integration time.
LIR	Line-Interlaced read with embedded line-resets (dual frame read 2R).
RLR	Reset-level read with embedded line-resets in front of line clocking (single frame read R).
ECR	End-of-line correlated read with embedded line-resets behind the line clocking (single frame read R).
FASTRESET	Just the fast frame reset (by line-resets).

6. SUBARRAY READOUT

To speed up the image frequency and to overcome the limitation of the image rate of a read mode by the fullframe readout time, GEIRS offers a general designed window logic. As less pixels are clocked in a readout mode the faster the image rate will be.

Example: mer-10 reaches saturation? ==> take parts of the full frame as windows and do the mer-10 in window mode, to reach a shorter integration time (see Table 3).

All readout-modes and the most options described in this document are also available for subarray (window) readout of the detector.

The needed timings (cycle time, minimal integration time, frame time, necessary waiting time used in the pattern, etc) are calculated directly out of the pattern commands, which were uploaded to the ROE.

GEIRS defines from the wanted windows the necessary frame pattern to clock each needed pixel just once.

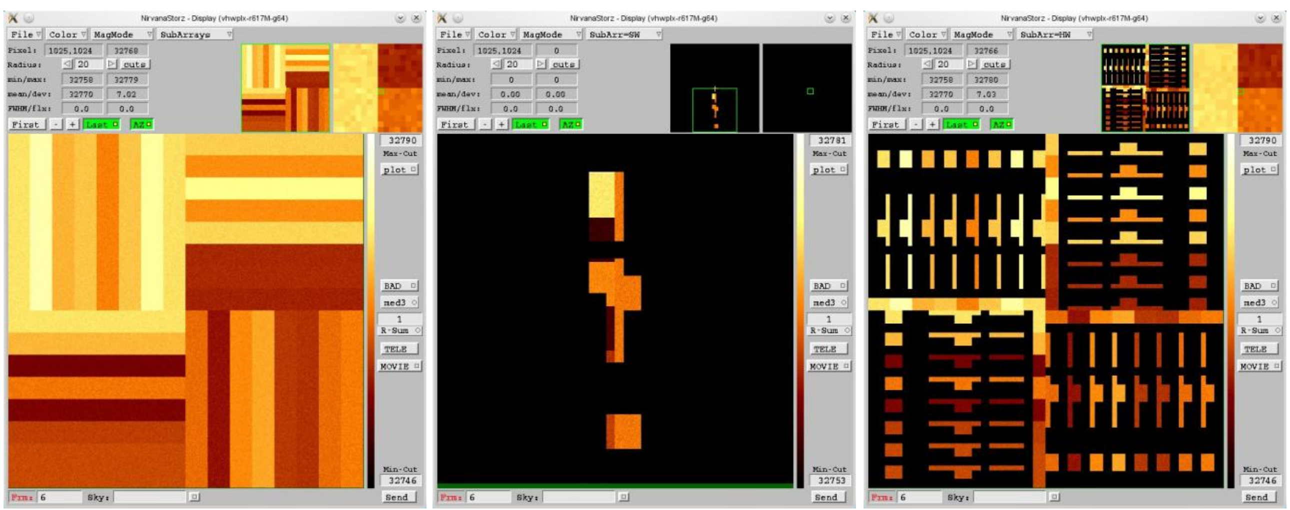


Figure 5: Single frame of Hawaii-2 with pure 32-channel ADC-offsets, detector cables just disconnected: On the left a full frame, in the middle a zoom on the 5 read rectangular SW windows with 60000 pixels, partly overlapping and also channel crossing. The necessary pixels to read are 34600, which are about ¼ of the full frame. On the right is the display switched to all incoming multichannel HW-windows. If the SW windowing is switched off after SW-windows settings, all 164 non overlapping HW-windows (5*32+4) will be used.

6.1 Windows readout frequencies

Using an HAWAII-2 the window areas have first to be addressed by skipping with high speed over the unused lines and pixels of a channel. To get maximal readout frequency of a single window in multichannel mode it should be exactly centered on the detector, which reduces the needed count of pixel-to-clock by the factor 4.

On an HAWAII-2RG in multi-channel mode the needed count of pixels to be clocked might be reduced by the factor 2, if a single window is centered exactly on a channel boundary and if the related window side is smaller in the length than the pixel count of a channel width.

The window readout is frame oriented, which means that for a single frame R in the readout schemes above always all pixels of all windows are addressed and read out once. Therefore the schemes and formulas above are also valid for our multi windows readout, just use the according frame time R of the multi window frame read.

In Table 3 we have listed examples of the window readout speed at science clocking speed.

Table 3: Windows are available in all readout modes; ffprot is the full frame protection reset (resetting also all lines where no pixels are readout). The given values are based on a pixel clock of 66kHz.

Readout mode	*Maximal image rate [Hz] of a centered window on HAWAII-2 (DIT = minDIT)*							
	128 x 128		*32 x 32*		*16 x 16*		*8 x 8*	
	*ffprot **ON***	ffprot **Off**	*ffprot **ON***	ffprot **Off**	*ffprot **ON***	ffprot **Off**	*ffprot **ON***	ffprot **Off**
rrr-mpia [fcr]	*7.56*	7.92	*64.9*	108.7	*107*	325	*128*	672
full-mpia [**lir**]	*7.70*	7.88	*77.5*	102.0	*146*	377	*189*	942
mer-6 [fowler-3]	*2.52*	2.67	*21.6*	36.5	*36*	108	*43*	224
msr-(N+1) *(1gap/Nimg)*	*15.13*	15.84	*129.9*	219.0	*213*	649	*256*	1343
cntsr-6	*2.52*	2.67	*21.6*	36.5	*36*	108	*43*	224

7. OPTIONS AND EXTENSIONS

Different kind of options are directly controlled via a GEIRS command or may be modified in a kind of configuration file of the detector engineering interface: Selection of the pixel clocking time; setting of the reset signal pulse timing, of the sync clocking speed and the skipping speed; activation of the full-frame protection for windowing and of the overflow protection of full frame readout; and last but not least the selection of a pixel multisampling count done either by the ROE ADC-FPGA (count 1,2 or 4) or later also by the data acquisition SW.

7.1 Cycle oriented multi windowing to get shorter minimal DITs for fullframe

The standard multi-window logic described above clocks for each frame through all pixels of all windows, which results in optimal integration efficiency for all windows.

To reach a shorter integration time than what is possible with normal fullframe clocking of double correlated read modes we use a multi-windowing technique, where each single window is clocked first as full cycle of the readout mode before going to the next window: By moving windows of full line width and a binary count of lines as height over the detector, we read the so called shortint-fullframes, where the minimal possible integration time is given by the binary count of lines used in the window, which is moved over the full detector size (Smallest DIT is hereby reached with a 1 line window, which is identical to lrdtime).

On detectors with strong temporal voltage drifts and/or strong ramps, the double correlated shortint readout might produce strange effects per window readout.

7.2 Preview on new extended readout modes

We are currently investigating on making real use of some, since longer time via pattern generator and ADC FPGA of the ROE, prepared features to combine and embed multi window read out modes for any detector channel count into a scientific readout mode. Possible applications for these are fast guiding and some other ideas.

8. EXPERIENCES

Nearly each of the HAWAII-2 detectors, which we have tested so far, had its own unique behavior.

Some showed more or less strong ramps and/or voltage drifts which resulted in different first frames or even different first images of repeated readout cycles. Some worked only well with most readout modes when using the idle-wait mode and the idle type ReadWoConv.

One detector (Omega2000[4]) got only scientific results with the full-mpia/lir readout, even in idle-break mode without significant first frames or image artifacts.

Another detector (first Lucifer1 detector[8]) had no temporal drifts and ramp effects and showed even best cosmetic images in the o2dcr-readout, even though this mode is delivering on many detectors strong ramps in the first frames.

And one detector (second Lucifer1 detector) was working without strong ramps and temporal drifts, but it produced strange columns, which prevented a scientific data reduction. But by moving away from a stabilizing pixel position during the integration time, we reached scientific results on the cost of very strong temporal drifts, immediately appearing if the detector was not clocked for a short time. These first frames, for example both frames of the first fowler pair in mer readout mode, have therefore to be skipped, which increases cycle time and minimal DIT.

9. CONCLUSION

Normally the most interesting because most efficient full-mpia/lir readout mode is a good solution, probably because it prevents temporal drifts by clocking directly before and after the reset-signals. It therefore often shows the detector static pixel behavior sharper than with other modes, where these characteristics might be hidden a little by temporal or floating voltage drifts.

For the future the cntsr and licntsr might get more interesting. One reason is the stabilizing effects of the continuous detector clocking and the other the ongoing move of IR-instrumentation to spectroscopic capabilites, which need long integration times.

Which readout modes are offered to the observer, decide at the end the PI and/or the commissioning team. This may include modifications of the readout modes according instrument and detector needs.

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