FLIR Systems
Advanced Thermal Solutions

DP003U-B
BPR Procedure

BPR Procedure

Contents

1. Specific Terminology

BPR: Bad Pixel Replacement (Bad Pixel Replacement)

BP: Bad Pixel(s)

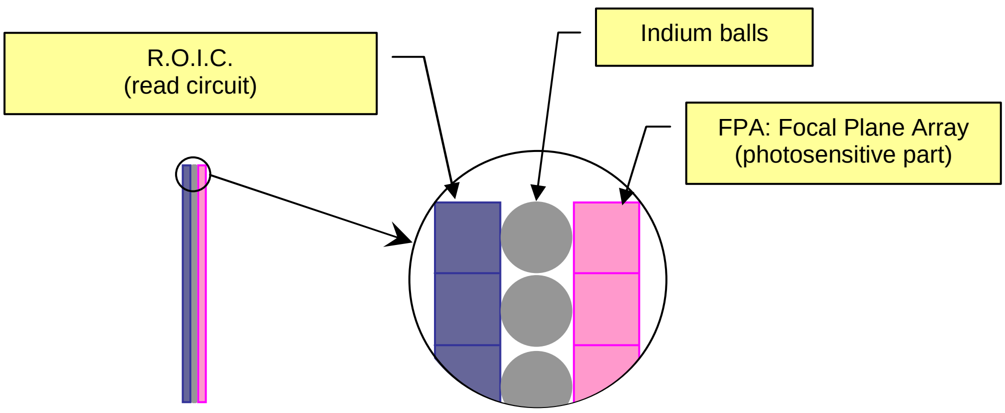
NUC: Non Uniformity Correction

Flash memory: Non volatile memory built into the camera used to store the operating parameters. These parameters are automatically loaded on power up.

2. What is a Bad Pixel?

Your camera is fitted with a matrix detector, i.e. made up of a matrix of basic detectors that are all separate from each other. Every detector element sends back a measurement that corresponds to a dot (or pixel) in the picture produced.

The detector matrix comprises a very large number of elements[1] some of which may present defects due to the technology used. This high technology approach comprises placing Indium balls (one per element) between a photosensitive plate and a read circuit. These balls ensure proper contact between the two plates for each of the two elements (i.e. one ball every 15 to 30 µm!). The size of the elements and the procedures usable to date necessarily induce connection defects affecting a few elements. These are called "bad pixels".



Detector cross-section view

Furthermore, the performance of each basic detector can be characterized by three data items that relate to the electrical measurement that it sends back:

- Its level (or offset)
- Its sensitivity (or gain)
- Its noise level

[1] Examples: JADE: a 320 x 240 matrix (76,800 pixels) - EMERALD: a 640 x 512 matrix (327,680 pixels)

To form an image that reflects the measurement, the offset and gain for every element are corrected (NUC) so that the value sent back by each element equals the overall average when all elements are simultaneously placed in front of the same temperature reference:

$$Y_{ij} = \alpha_{ij} X_{ij} + \beta_{ij} = \text{average of } X_{ij}$$

With:

- $X_{ij:}$ response from the element with coordinates ij before correction
- Y_{ij}: response from the element with coordinates ij after correction
- α_{ij} : gain correction for the element with coordinates ij
- and β_{ij}: offset correction for the element with coordinates ij

The elements with characteristics that diverge excessively from the average values are also considered as faulty (see below for the method used to determine when pixels are bad).

A pixel can also be classified as a bad pixel due to its noise level.

The software used by your measurement system will correct these missing pieces as well as possible by filling the "holes" with a replacement value taken from a pixel located close by.

A bad pixel is therefore defined by its address and the address of its replacement. Consequently there are two contiguous (or close by) points that return the same value.

3. Bad Pixel Replacement Algorithm (CEDIP proprietary)

The bad pixel is replaced by one of its non-defective neighbors. The algorithm tests up to 48 neighboring pixels in the order shown by the numbers in the table below, until a good pixel is found (when the bad pixel is located at the detector's edge, numbers that do not correspond to any pixel are ignored).

Y \ X	0	1	2	3	4	5	6
0	45	37	29	25	30	38	46
1	44	21	13	9	14	22	39
2	36	20	5	1	6	15	31
3	28	12	4	☒	2	10	26
4	35	19	8	3	7	16	32
5	43	24	18	11	17	23	40
6	48	42	34	27	33	41	47

The bad pixel (3,3) is replaced with the value of the pixel above it (3,2). If this replacement pixel too is bad, the value returned will be the one of its right hand neighbor (4,3), etc.

This transformation is performed by the camera in real-time, after running the NUC process.

FAQ: Does the number of bad pixels change over time?

No. The number of pixels with an electrical defect (relating to their manufacture) will not evolve over time. On the other hand, depending on the Integration Time that you use, the characteristics of certain pixels (their gain and offset) may bring you to exclude them or alternatively bring them back in.

This is because the Integration Time, through its influence on the read mode may influence the impact of the bad pixels. As a result, every NUC has a list of bad pixels.

Note

The number of bad pixels is always negligible compared with the total number of pixels in the detector. Consequently there is no point in spending a lot of time to correct for every last bad pixel.

4. How do I Determine the List of BPs?

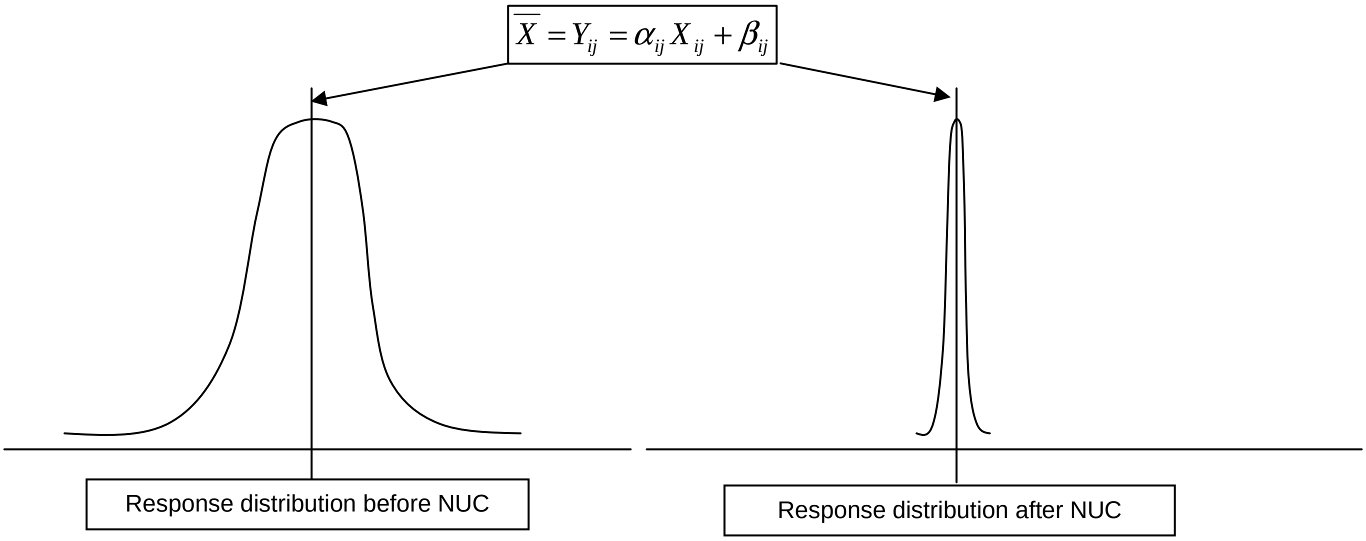
As described above, there are three possible reasons for determining that a pixel is bad:

- Bad gain or no gain (connection defect at the Indium ball level)
- Excessive offset
- Excessive noise level

The camera characterization determines these three characteristics for each of the pixels.

Reminders on NUC:

The NUC applies a level (gain) and absolute value (offset) correction based on the average responses.



Consequently, the average response level was not changed and:

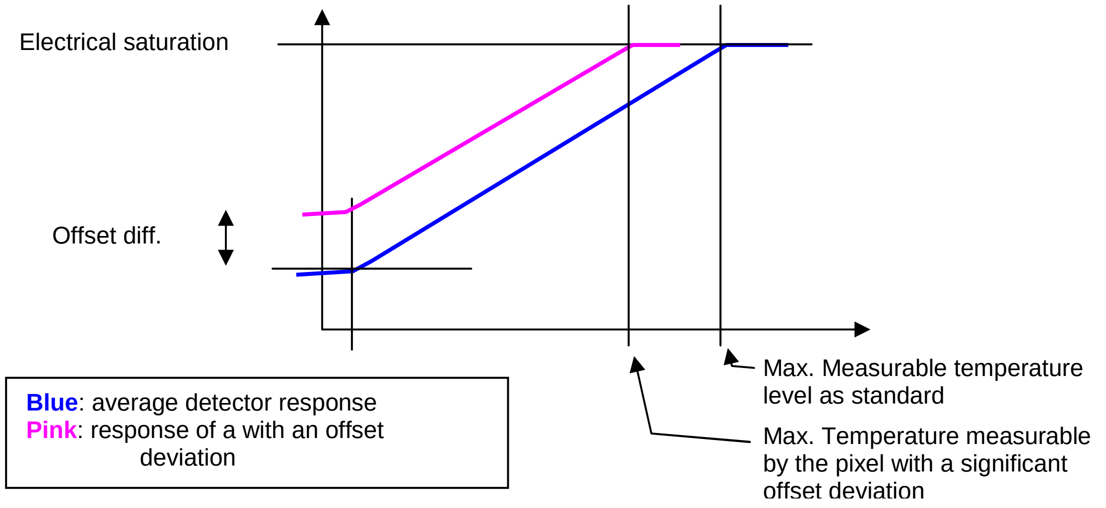
$\overline{\alpha_{ij}} = 1{,}00$ $\overline{\beta_{ij}} = 0{,}00$

4.1. *Failure Caused by the Level (Gain)*

A pixel that has a level far different from the average one requires significant correction (α far different from 1.00). It is therefore possible, using the NUC tables, to determine which pixels require correction in excess of a given threshold. The values applied as standard are α < 0.75 or α > 1.25, or a gain that differs from the average level by more than 25%.

4.2. Failure Caused by the Absolute Value (Offset)

A detector element that shows a significant offset in relation to the average level is subject to the same electrical saturation (linked to component technology), resulting in a limit to the maximum measurable temperature level. In this case, the element's response is not reliable enough and it is considered to be a bad pixel.



We recommend setting the limit offset correction criteria at 30% (or approximately 5,000 in digital level notation).

Warning

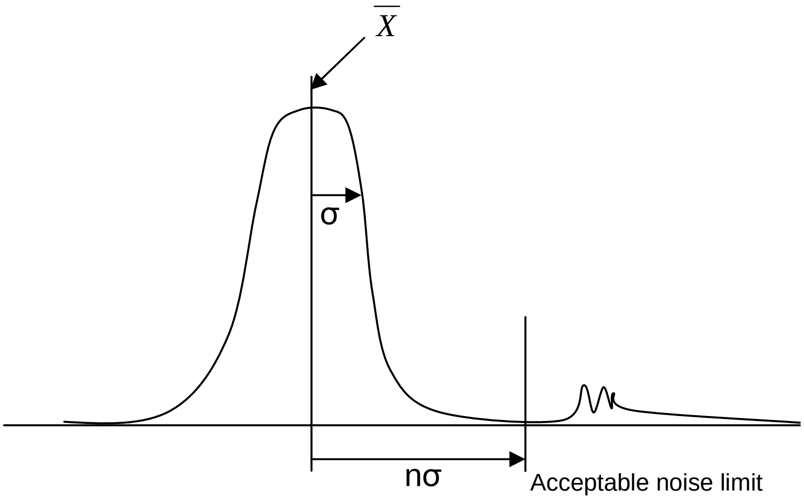
An incorrectly completed NUC will lead to producing a bad list of bad pixels.

Consequently, an abnormally long list of bad pixels is revealing of a NUC problem. Example: An error in the choice of the high temperature reference point will lead to saturation (or a situation close to saturation that is not always perceptible). The number of pixels with a high degree of offset correction will therefore be a high one and the list of bad pixels will be a long one.

4.3. Failure Caused by Noise

Any element that presents an excessive time noise level must be considered to be faulty.

The noise measurement is performed by comparing the value returned by the element during a given length of time when placed in front of a fixed scene (no temperature variation). This is the same as calculating the standard deviation in time for each element and generating the corresponding noise matrix.



Response distribution when faced with a fixed scene

The elements that show a noise offset that exceeds nσ will be considered to be bad pixels.

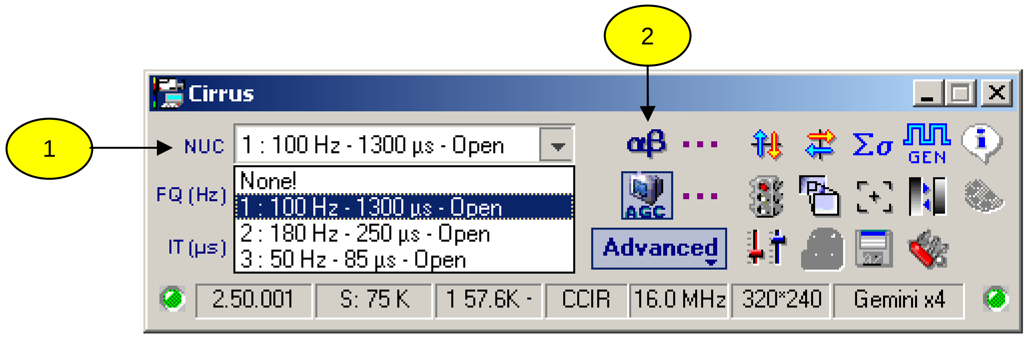
Note

During the noise measurement, no variation due to the scene should be detected. The scene must therefore be a fixed one and not present contrasting "edges" that could, by moving from one pixel to another, upset detection. For this same reason, we recommend unfocusing the entire optical assembly.

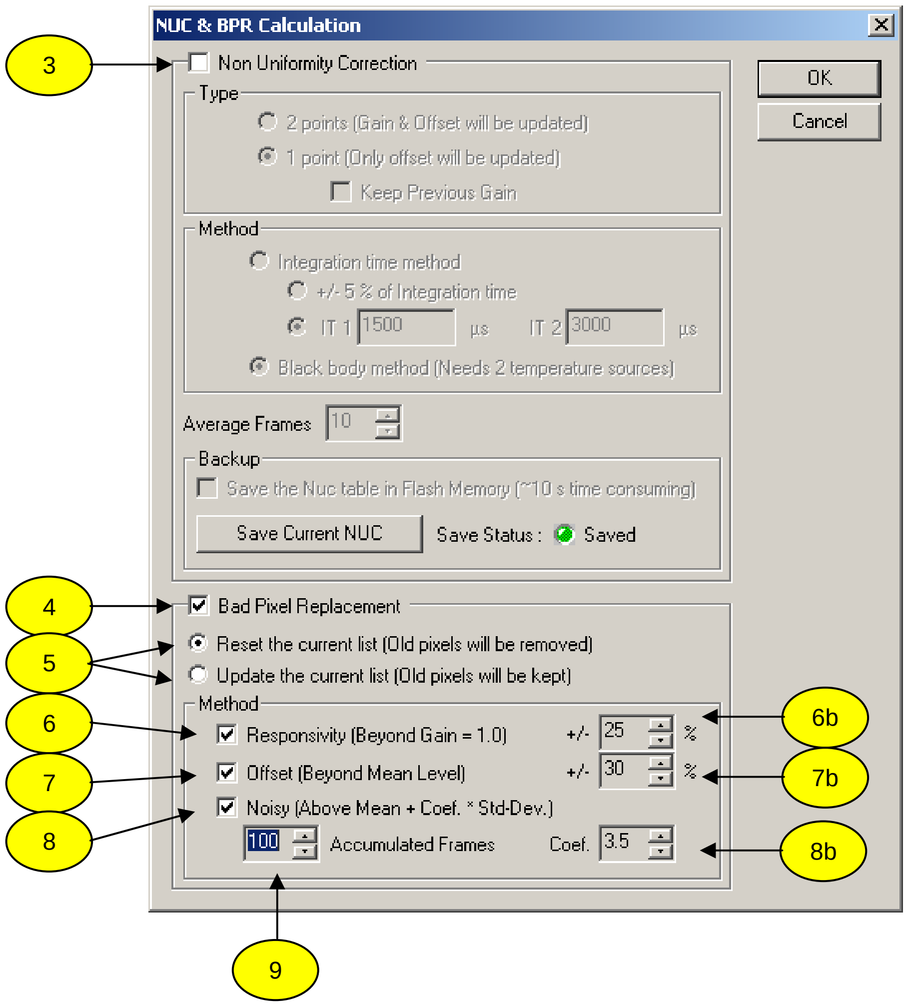
5. BP Detection Operating Mode

Load the CIRRUS software.

Select the NUC table in relation to which bad pixel detection is run (1), then click on the "αβ" button (2).



The window below opens:



Make sure that NUC is not selected. Untick this box if necessary (3).

Tick the "Bad Pixel Replacement" box (4).

Choose whether to replace the existing list or to complete it with the newly detected bad pixels (5).

Note

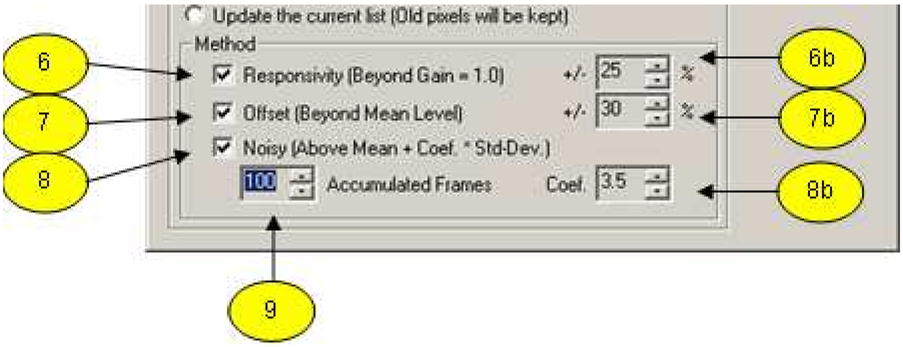
Pay attention to the list update choices. Cumulating bad pixels from a number of detection approaches may become too restrictive compared with the measurement to be performed.

Warning

Using a cooled JADE camera, the list of bad pixels is automatically saved to the camera's flash memory. The previous list is therefore updated.

On the other hand, using EMERALD and JADE UC, it is necessary to perform your own save to Flash memory so that the up to date list will be loaded on the next power up.

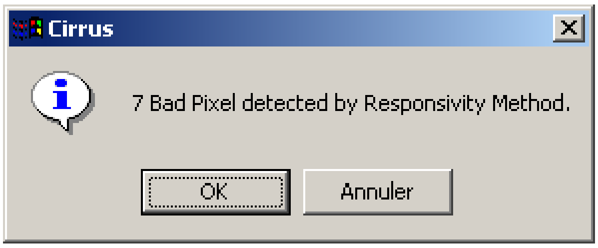
In the "Method" field:



For gain based detection:

- Tick the "Responsivity" box (6).
- Set the gain correction limit beyond which the pixel will be declared bad (6b). Recommended value: 25%.
- Click on the "OK" button.

At the end of the detection process, the following window will appear to show the number of bad pixels found using the responsivity (gain based) method:



Click on the "OK" button to move to the next step.

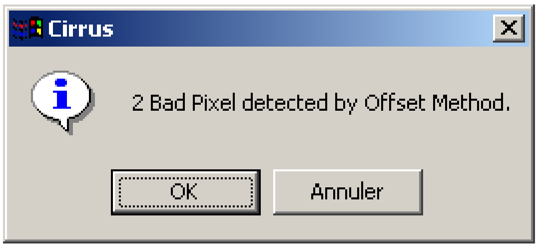
Warning

Pressing the "Cancel" button will end the bad pixel detection process. This does not cancel the current list update. This remark applies to all three modes.

For offset based detection:

- Tick the "Offset" box (7).
- Set the limit to offset correction beyond which the pixel will be declared bad (7b). Recommended value: 30%.
- Click on the "OK" button.

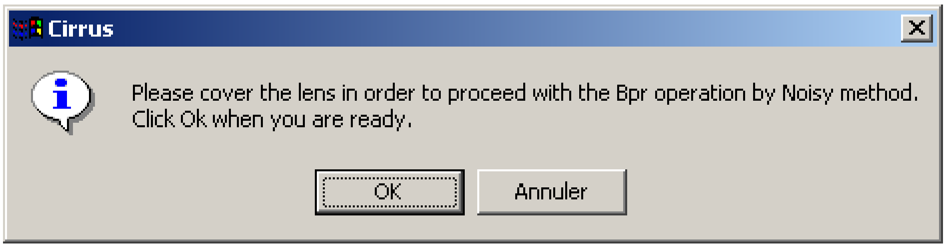
This measurement lasts a few seconds to a few minutes, depending on the number of bad pixels detected. At the end of the detection process, the window below appears showing the number of bad pixels found by the offset method:



For noise based detection:

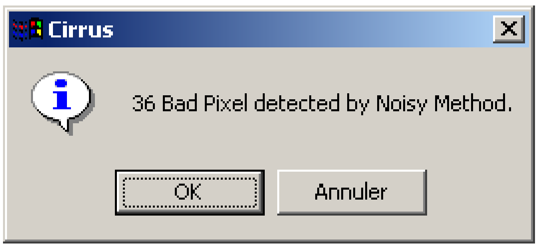
- Tick the "Noisy" box (8).
- Set the standard deviation multiplication coefficient beyond which the pixel will be declared as bad (8b). Recommended value: 3.5.
- Enter the number of images over which the noise level will be measured (9). Recommended value: 100.
- Click on the "OK" button.

The following window is displayed:



Cover the camera lens (to produce a fixed scene with no contrasting edges) then click on "OK".

At the end of the detection process (that last approximately one minute for 100 images), the window below appears showing the number of bad pixels found by the noisy method:



Click on the "OK" button to finish detection.

Note

It is possible to cumulate two or three methods in a single operation. Pressing the "OK" button after each detection sequence will activate the next one. The "Cancel" button cancels the remaining detection sequences (but not the previous one).

6. Recovering the List of BPs on the PC

At this stage, the list of bad pixels is stored in the camera's Flash memory. It is possible to transfer it to the PC to:

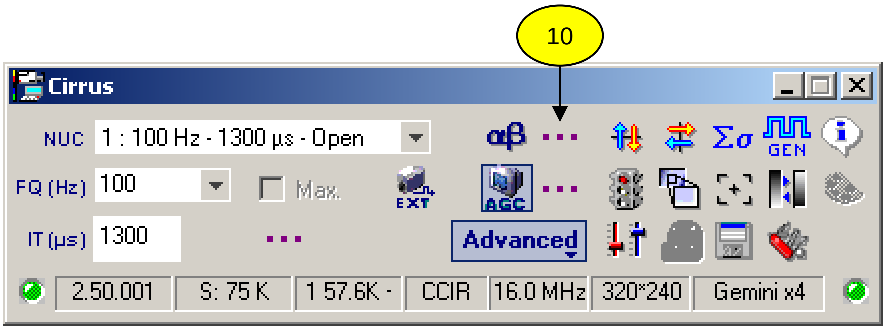
- Obtain the list of bad pixels
- Display their position
- Manually add a pixel that may have escaped detection

Note

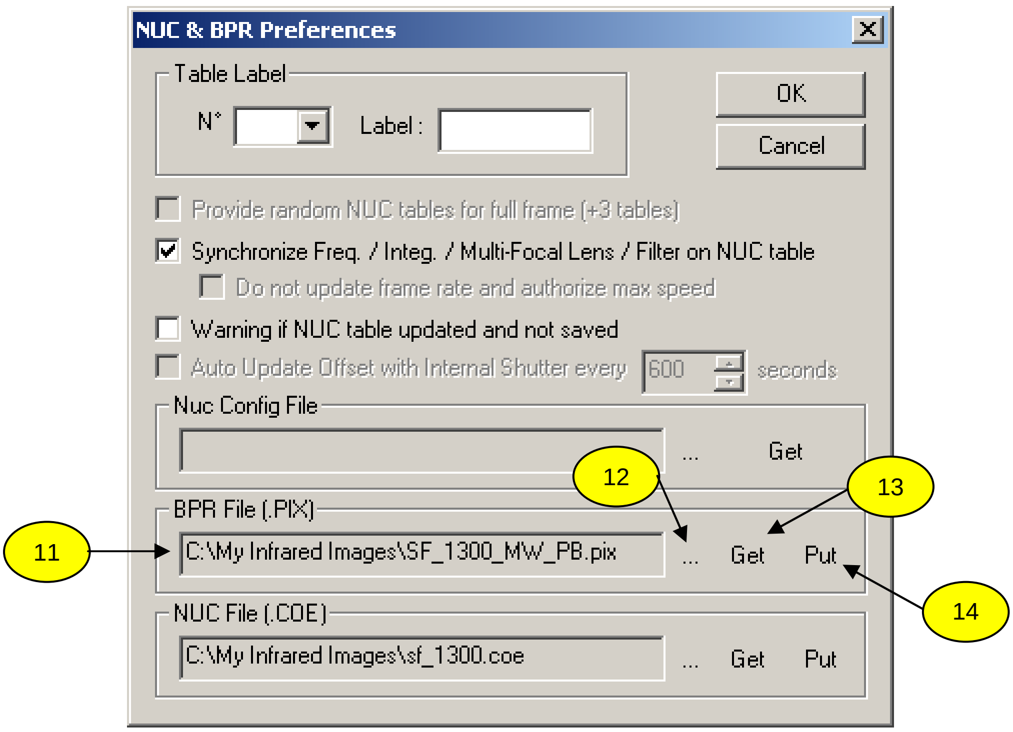
This function is not available when using a JADE UC camera.

6.1. Transferring the List of BPs from Camera to PC

From the CIRRUS software main screen, click on the "αβ preferences" button (10).



The "NUC & BPR preferences" window is displayed:



Use the "BPR File (.PIX)" field to fill in the access path and the filename that you would like to assign to the list of bad pixels (11). Use the explorer called up by the "…" button to the left of the data entry field (12) to help you.

Transfer the list of bad pixels to this file by clicking on the "Get" button (13).

Note

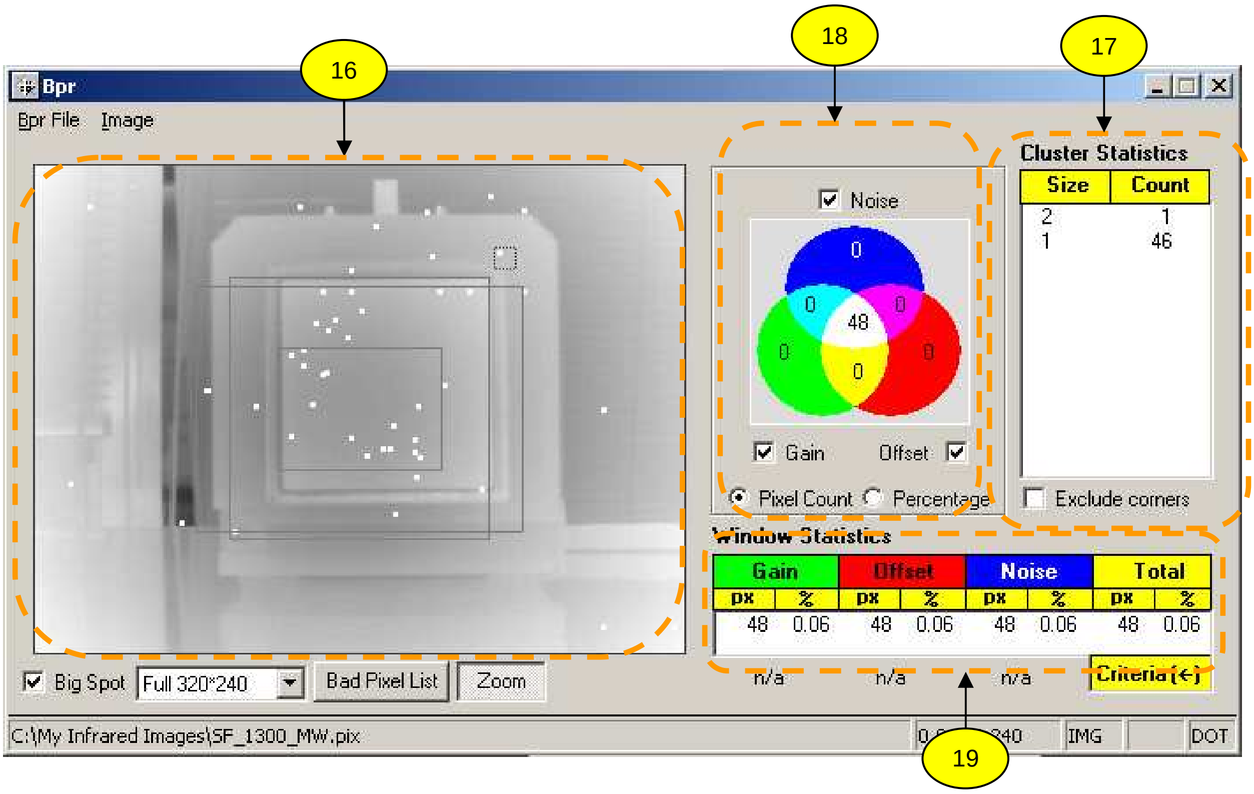
For a definition of ".pix" files, refer to the Altair reference guide.

6.2. Viewing BP Parameters

Start the "BPR Viewer" utility supplied with Altair (refer to the Altair User's Guide). This software is used for viewing.

Open the ".pix" file that contains the list of bad pixels you wish to view.

The following window is displayed:



This screen shows:

- In field (16): the locations of the bad pixels
- In field (17): a count of the bad pixel clusters (in this case, one cluster of two and 46 isolated pixels)
- In fields (18 and 19): the list of causes for classification as bad pixels

Note

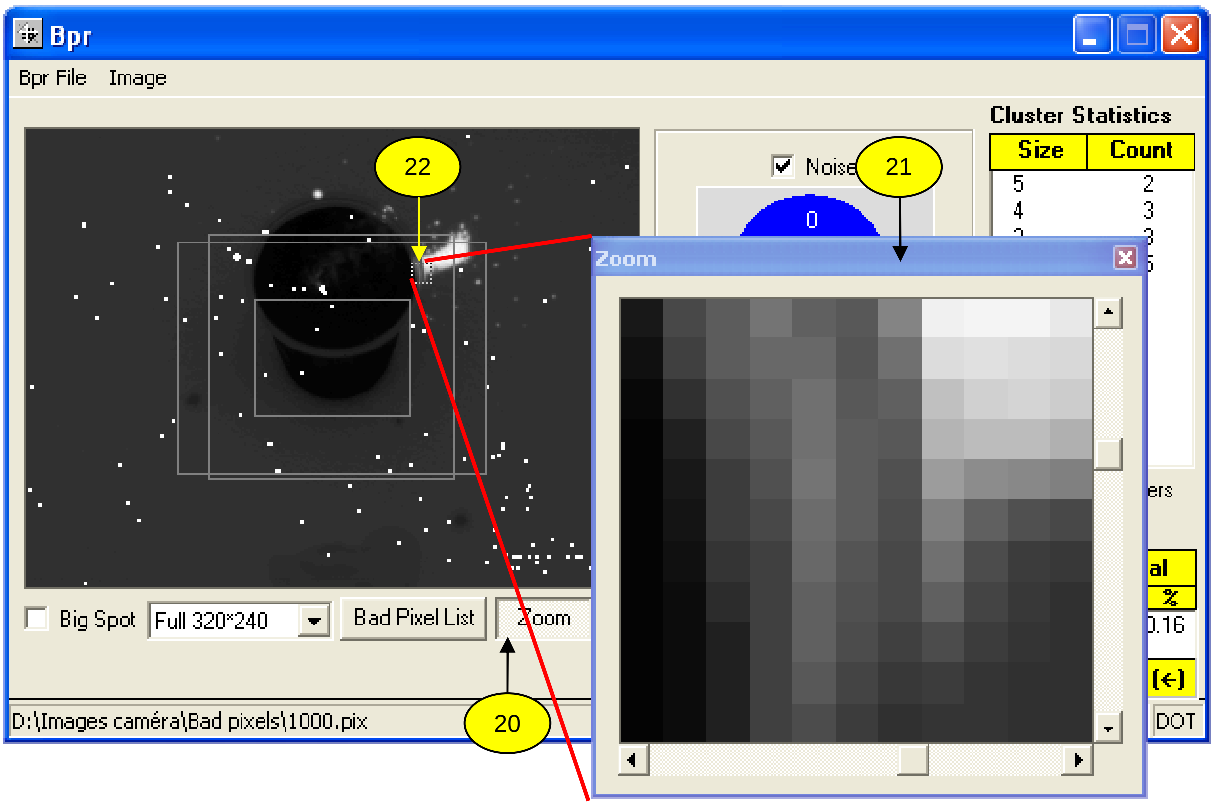
The list of causes for classification as bad pixels is only operational for detections performed from "BPR Viewer" and not for detections performed from "CIRRUS" (the camera's memory is not designed to store this data).

6.3. Rekeying the List of BPs to PC

In some cases, the image may show bad pixels that have not been detected automatically. It is possible to mark them manually by proceeding as follows:

From "Altair", capture a picture in "real-time" (using the  button) and save it in a file.

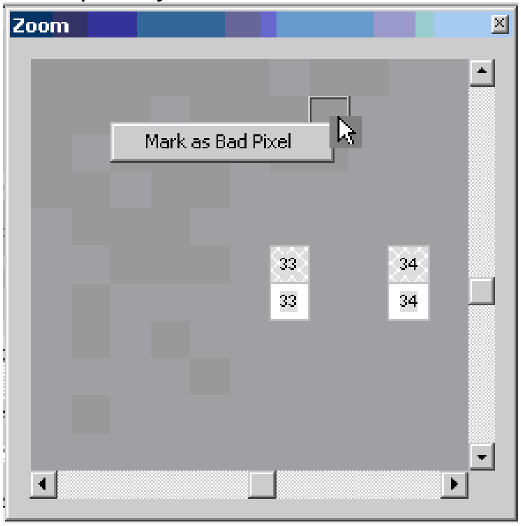
From "BPR Viewer", load the image, then click on the "ZOOM" button (20).



Using the zoomed window's scroll bars (21), move the zoomed area (22) to view the pixel to mark.

In the zoomed window (23), click on the pixel to mark using the right mouse button, then click on the "Mark as Bad Pixel" button to confirm bad pixel marking.

Repeat the operation for all of the pixels you wish to add to the list.



Record the changes made to your file using "Bpr File\Save".

Note

The ".pix" files generated by CEDIP when manufacturing your camera are provided on the supporting CD.

6.4. Transferring the List of BPs from PC to Camera

From the CIRRUS "NUC & BPR preferences" screen, use the "BPR File (.PIX)" field (11) to fill in the access path and the filename containing the list of bad pixels to be sent to the camera. Use the explorer called up by the "…" button to the left of the data entry field (12) to help you.

Transfer the list of bad pixels to this file by clicking on the "Put" button (14).