The Fire-i camera dead 1-st bit problem

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Inspection of the output data numbers obtained from Fire-I board BW camera shows that the numbers have always clear 1-st bit. We use the bits numeration from 0 (LSB) to 7 (MSB). This defect brings down the performance of the camera. Below we compare two strategies for data processing: 1) to ignore 0-th bit and use camera as 6-bit depth one, 2) to use 0-th bit ($6\frac{1}{2}$-bit depth camera).

For this we simulated a camera frame with random normally distributed discrete signal. The signal has a mean bias value M and noise variance σ^2. Its discretization corresponds of unit in 0-th bit. Further, we computed the measured mean and measured variance depending on signal level and noise variance. The results are presented on the Fig. 1 and 2. The input signal range is adopted from 16 to 20 but it is clear that the results are the same for any range with period as equal as 4. In real we don't know input level a priori, so we plot the graphs as function of measured mean (output).

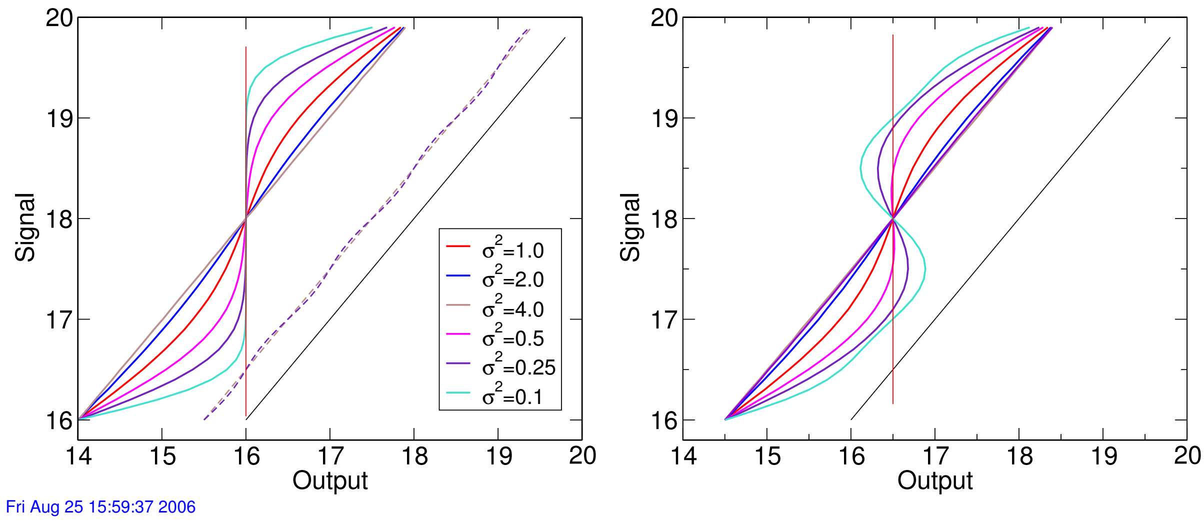

Рис. 1: The input signal level as dependence on measured mean level for the different input noise variance. On left — 6 bit discretization (case A), on right — case B (($6\frac{1}{2}$-bit). Red vertical line is reference one. For comparison, black solid line — ideal digitization, black dashed — 8-bit digitization.

In point of fact the first strategy (A) leads to well known discretization problem for case of 6 bit, the second one (B) is more complicated. Fig. 1 presents the dependence of measured (computed) mean of the input signal. One can see, the these two experiments have similar dependences, but there are two features: 1) for case B a systematic shift (1.5 units) is a little less than for the A (2 units) and 2) for case of small input noise $\sigma^2 < 0.5$ we have uncertainty for A and have non-uniqueness for B.

The both effects are bad, because we aren't able to restore correctly input signal, but the problem is localized close near output value 16 for case A and distributed in wide range for case B.

Fig. 2 presents the measured signal variance as function of the mean output. Also, there are two features: 1) for the case A the discretization noise is a little less than for the case B, 2) but in the case of small input noise, for case A there is limitary dependence, for case B — is not. For case B, the non-uniqueness of variance is detected, too.

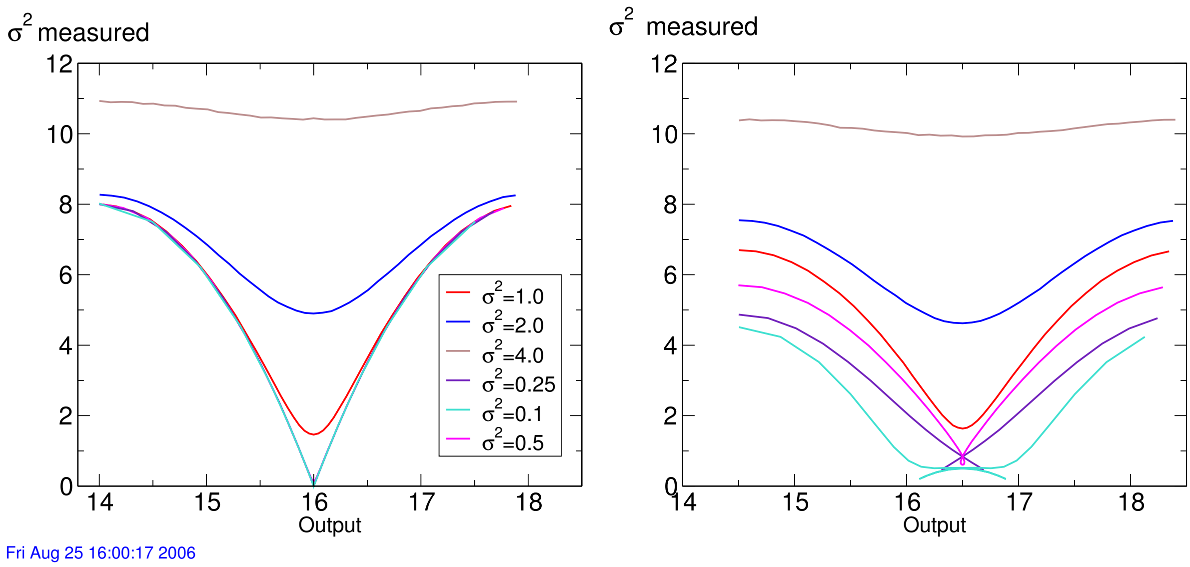

Рис. 2: The "measured" variance as dependence on output level for the different input noise variance. On left — 6 bit discretization (case A), on right — case B (($6\frac{1}{2}$-bit).

Again, both cases are identical practically. The presence of the active 0-th bit doesn't change situation. It is bad news, because our measurement shows that camera has readout noise as small as $18 \pm 2 \quad e^-$ only. Since capacity of ICX098 pixel is about $10000e^-$ the conversion factor (camera gain) must be $\approx 40e^-$ per digit number (ADU) to provide full camera performance. It corresponds to the $\sigma^2 \approx 0.2$ in ours calculations. In worst case the measured noise will be as large as $88e^-$ for the case B and $113e^-$ for the case A strategy. The small advantage of the case B before the case A is observed but in the case A a restoration of more exact input noise value is possible due to more simple dependence on mean level.

Below we present the results of real measurements with Fire-i camera. During data processing the 0-th bit is cleared to provide the case A (6-bit camera). The very short exposure was set to eliminate external light. The level of input signal was changed with help of Brightness control, which is added in analog tract before digitization. One can see that the variance dependence shows that input noise is less than 0.5 definitely. The mean value functions are sensitive to input variance variation in range 0 – 0.5 and permit to determine its value despite of crude digitization (remind that in discussed case the digitization increment is equal 4).

It is no wonder, because we use calibrated bias shift which is finer than digitization increment to do fine scan of the input signal. During normal measurements, such method is not appropriate, so this camera is able to work as 6-bit camera only.

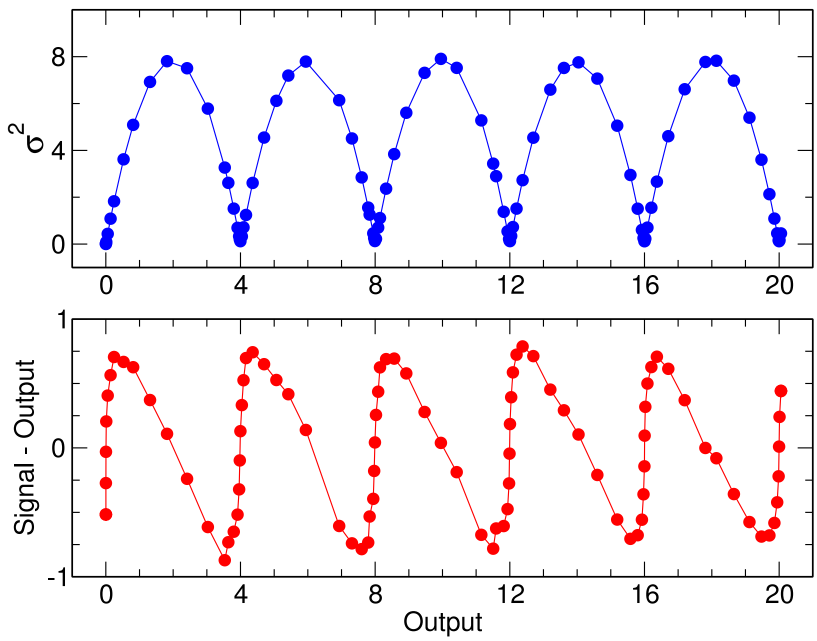

Рис. 3: The really measured variance as dependence on output level. The 6-bit digitization, variance of input noise is about 0.25 or RON=$16e^{-}$ (top). The difference of the input and output signals (bottom).