Characterisation report

Session 20261006-173009_libcamera | IMX477 / SBGGR12_CSI2P

SENSOR
IMX477
4056 × 3040, BGGR

RAW
12 bits
SBGGR12_CSI2P

CONVERSION
2.308 e⁻/ADU
PTC · gain 1.000

TEMPERATURE
0.4 °C
8 missing telemetry readings

Results summary

Main results and limitations of interpretation.

PTC analysis

VALIDATED

Conversion gain: 2.308 e⁻/ADU

Dynamic range: 11.11 stops

Saturation observed; effective capacity and dynamic range calculated from the range actually used before clipping.

Quantities not established: unavailable.

Dark-current analysis

VALIDATED

Dark-current analysis: VALIDATED

Typical current: UNRESOLVED

Thermal analysis status: VALIDATED.

Exposures: 8 steps, from 0.1 to 300.0 s

A negative slope means neither negative nor zero current.

Measurement quality

Analysis validity status, independently of the measured result.

Raw data format (RAW)	VALIDATED
Read noise	VALIDATED
PTC / linearity	VALIDATED
Dark-current analysis	VALIDATED
Thermal stability	VALIDATED

Interpretation criteria

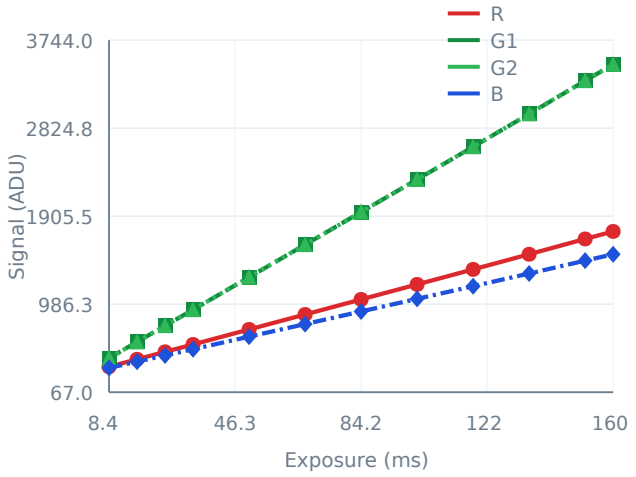
Conclusions prioritise stable, reproducible measurements.

- Conversion gain is estimated in the linear region of the PTC.
- Clipped points or points outside the measured linear region are excluded from the fit.
- Long dark exposures can be interpreted if temperature remains stable.
- Temperature is quantised to degrees, with a 2 °C peak-to-peak margin.
- On resuming acquisition, only thermal telemetry is missing; images are retained.

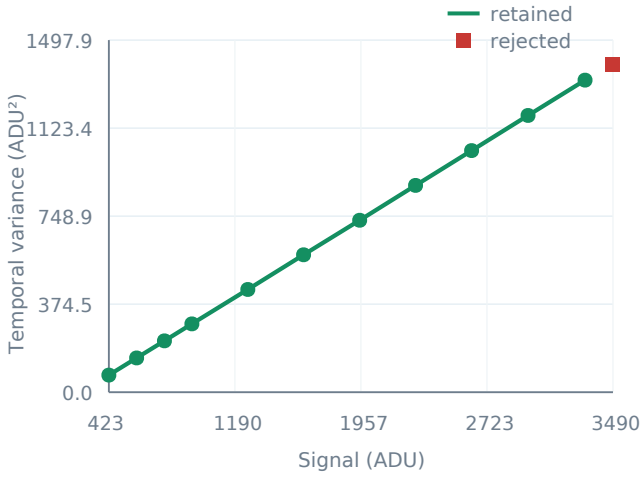
Measurement plots

Signals, read noise and thermal drift

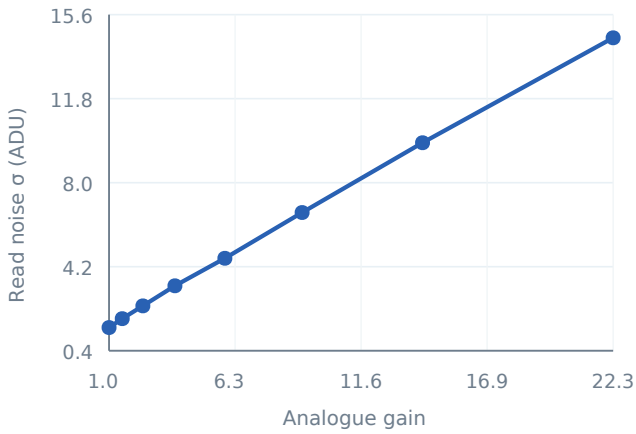
Response curve / linearity



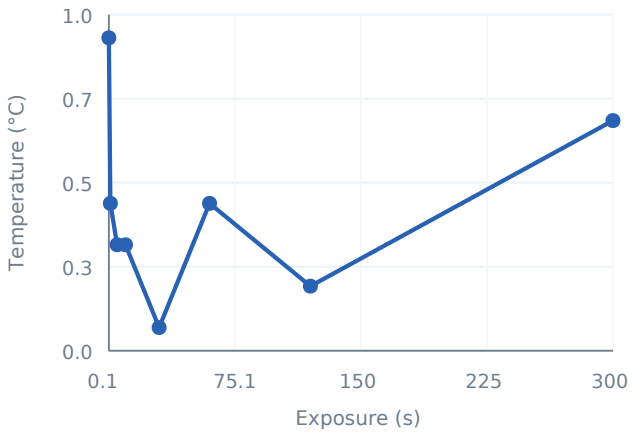
Photon transfer curve (PTC)



Read noise



Mean temperature by exposure step



Interpretation

The PTC slope provides an estimate of conversion gain.

Usable dynamic range combines the raw data (RAW) range and read noise.

Long dark exposures are conclusive only at a stable temperature.

Statuses describe analysis validity, independently of the scientific result.

Characterisation report

Detailed data and decision criteria

Raw data calibration (RAW)

Converted black level and available digital range at native bit depth.

Native bit depth: 12 bits

Source black level: 64 · 10 bits; converted RAW black level: 256

RAW white code: 4095; available RAW digital range: 3839 ADU

PTC calibration

Linear region, uncertainty and observed saturation.

Gain: 1.000; conversion: 2.3084 e^-/ADU ± 0.0013

R^2: 1.0000; acquired / retained / rejected levels: 12/11/1

Maximum clipping: 0.00169; threshold: 0.000100; saturation: observed

Range actually used before observed saturation: 3234 ADU

Corresponding effective capacity: 7465 e^-; dynamic range: 11.11 stops

Read noise

Pair differences; noise σ = standard deviation(A−B)/√2.

Gain	R (ADU)	G1 (ADU)	G2 (ADU)	B (ADU)	Overall (ADU)	Overall (e^-)
1.000	1.455	1.477	1.476	1.457	1.466	3.385
1.556	1.865	1.874	1.875	1.864	1.870	2.785
2.427	2.445	2.454	2.453	2.443	2.449	2.359
3.779	3.356	3.359	3.364	3.359	3.359	2.089
5.885	4.603	4.608	4.647	4.604	4.606	1.845
9.143	6.675	6.685	6.772	6.675	6.680	1.730
14.222	9.830	9.849	9.969	9.837	9.843	1.649
22.261	14.576	14.614	14.776	14.582	14.598	1.573

Conversion to e^- unavailable at gains without a corresponding valid PTC.

Dark current and hot pixels

Normal population, positive tail and global black-level drift.

Exposures analysed: 100 000 · 1 000 000 · 5 000 000 · 10 000 000 · 30 000 000 · 60 000 000 · 120 000 000 · 300 000 000 µs

Median population slope: -0.0058 ADU/pixel/s; p90: 0.0071; p99: 0.0319

Normal population: typical current unresolved against offset drift.

Hot pixels detected from changes with exposure time: per-pixel regression.

Threshold = max(10 × |median slope|, 6 × 1.4826 × MAD) = 0.0576 ADU/pixel/s; dominant branch: median slope

Tracked sample: 16 060 pixels; 23 detected (0.14%)
Global black-level drift: -0.002135 ADU/pixel/s ± 0.000953; R^2=0.455; slope not significant

Temperature

Thermal summary for long dark exposures.

Thermal stabilisation: 60 s pause between steps

Dark exposures: Tmin 0.0 °C, Tmax 1.0 °C, range 1.0 °C; 8 missing temperatures

Temperature / $\log_{10}$(exposure) correlation: r = -0.46

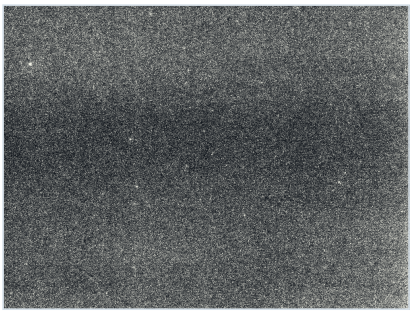
Thermal analysis status: VALIDATED

Derived spatial products

Spatial analysis of long dark exposures

Master dark - reduced view

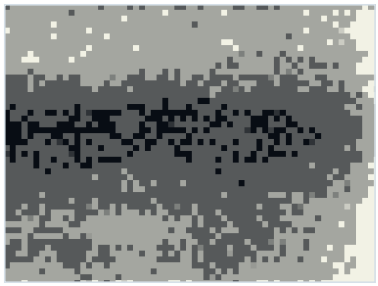
Full-sensor median master, area downsampled · ADU



Robust scale: 254.908 to 257.586 ADU

Low-frequency structure (reduced view)

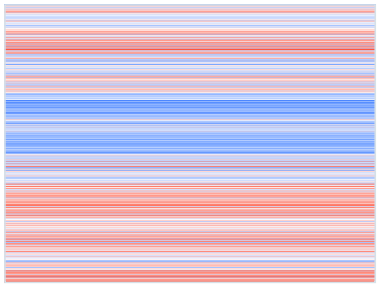
Bayer 2 × 2 · blocks of 32 × 32 cells
64 × 64 pixels · nearest-neighbour, no antialiasing · ADU



Robust scale: 255.250 to 256.000 ADU

Horizontal component

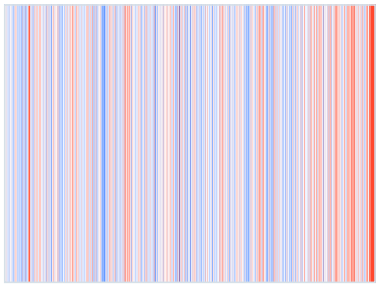
Reduced view · rendered map, mean per row
(reduced master − low frequency) · ADU



Scale: -0.117 to +0.117 ADU

Vertical component

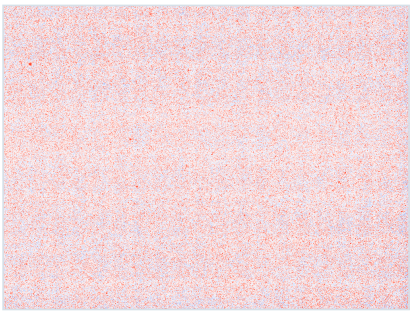
Reduced view · rendered map, mean per column
(reduced master − low frequency) · ADU



Scale: -0.115 to +0.115 ADU

High-frequency residual

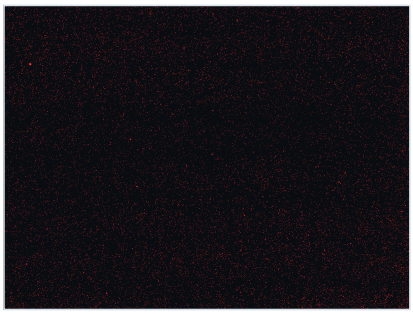
Reduced view · master − background − rows − columns · ADU



Scale: -1.888 to +1.888 ADU

Spatial hot-pixel candidates

Reduced view · threshold 1.5517 ADU · binary mask



Detected: 26392 / 785408 (3.36%)

Session: 20261006-173009_libcamera

Algorithm: spatial_dark_analysis 1.1 · Sensor: IMX477 · CFA BGGR

Master: integer temporal median of 10 frames, 4056 × 3040 pixels · 300.000 s · gain 1.000

View: area downsampling of the full-sensor master to 1024 × 767 pixels.

Native full-sensor measurements: integer median master; p99.9 mask; direct blocks of 32 × 32 Bayer cells.

Native profiles: Bayer mean − block median; median per row/column; centred profiles.

RMS of centred profiles: population standard deviation.

Rendered maps: horizontal/vertical components = row/column means of (reduced master − low-frequency background).

Low-frequency PDF: measured blocks, nearest-neighbour without antialiasing; bilinear reconstruction retained for H/V/residual.

Spatial candidates: reduced-view cells, not photosites; |residual| ≥ median(|residual|) + 6 × MAD(|residual|), else max(1e-9, p98(|residual|)).

Multi-gain PTC characterisation

Performance versus analogue gain

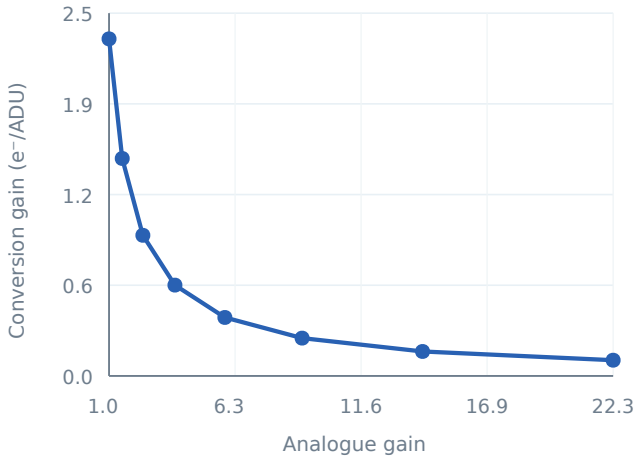
Measured analogue gains: 8

Regime change: no statistically demonstrated break

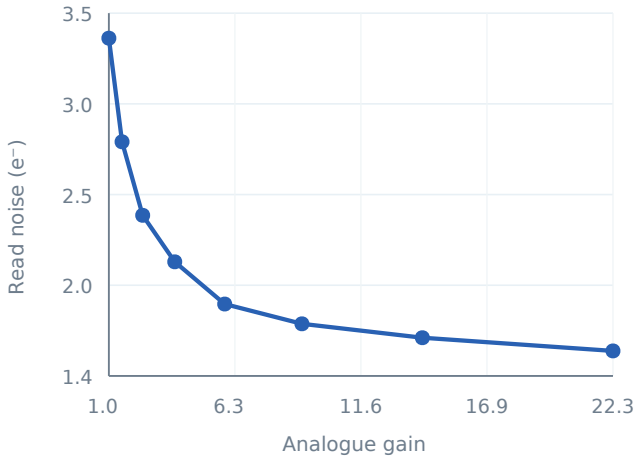
Selected continuous model: c(g)=exp(polynomial(log g)), degree 1, BIC 12.15, monotonic

Power-law comparison: C = 2.309; p = 0.988

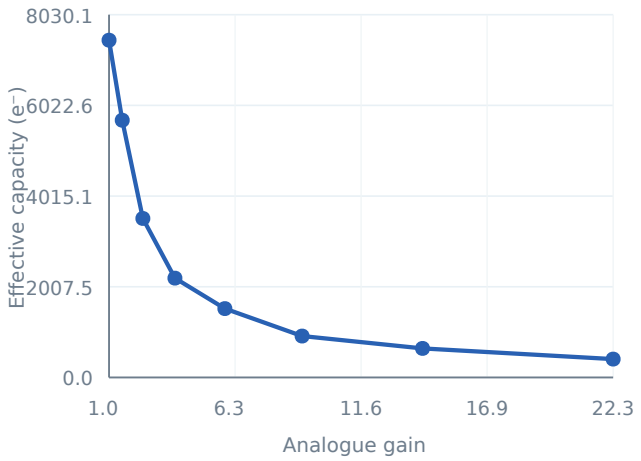
Conversion gain



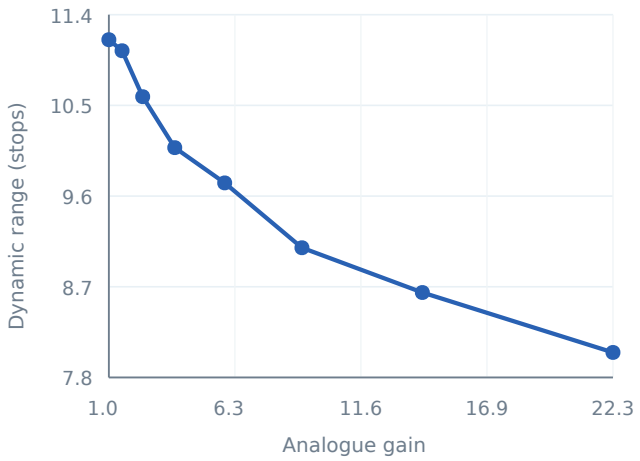
Read noise



Effective capacity before saturation



Usable dynamic range



Interpreting the results

Increasing analogue gain generally reduces read noise expressed in electrons, but also reduces the maximum charge measurable before saturation.

A candidate break must outperform the best continuous model (ΔBIC ≥ 6 and resampling p-value ≤ 0.01); it still requires confirmation through an independent campaign and is neither an optimal gain nor a recommended setting.

Multi-gain PTC details

Levels, pairs, effective capacity and clipping

All gains with a valid PTC are shown.

Effective capacity combines the range actually used before observed saturation and conversion gain; it does not describe the photosite's physical capacity.

Gain requested	Gain actual	Conversion e⁻/ADU ± unc.	Levels acquired / retained / rejected	Pairs	Retained signal (ADU)	Effective capacity (e⁻)	Clipping overall
1.000	1.000	2.3084 ± 0.0013	12/11/1	120	423.2 to 3320.1	7 465	observed
1.558	1.556	1.4893 ± 0.0023	12/8/4	120	518.1 to 3409.3	5 694	observed
2.427	2.427	0.9632 ± 0.0013	12/9/3	120	459.2 to 3108.9	3 519	observed
3.780	3.779	0.6220 ± 0.0007	12/11/1	120	413.7 to 3110.3	2 198	observed
5.889	5.885	0.4005 ± 0.0005	12/8/4	120	502.1 to 3229.1	1 524	observed
9.173	9.143	0.2590 ± 0.0002	12/9/3	120	447.8 to 2939.2	917	observed
14.290	14.222	0.1676 ± 0.0002	12/6/6	120	553.8 to 2630.7	643	observed
22.261	22.261	0.1078 ± 0.0001	12/8/4	120	487.7 to 3050.0	407	observed

Clipping observed globally through the fraction of photosites at white code; clipping by CFA channel is not measured.