VERA C. RUBIN OBSERVATORY

LSST Teledyne e2v CCD Characterization Under Varying Operating Conditions

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Introduction

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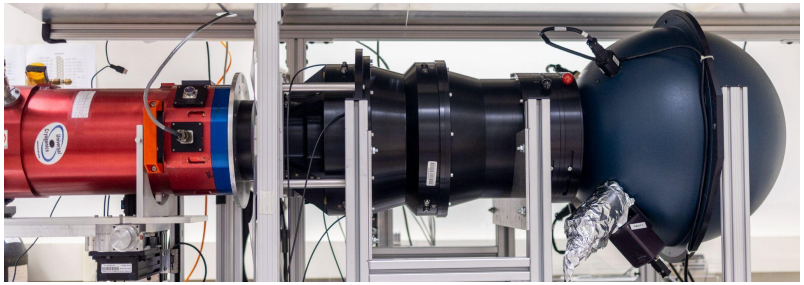
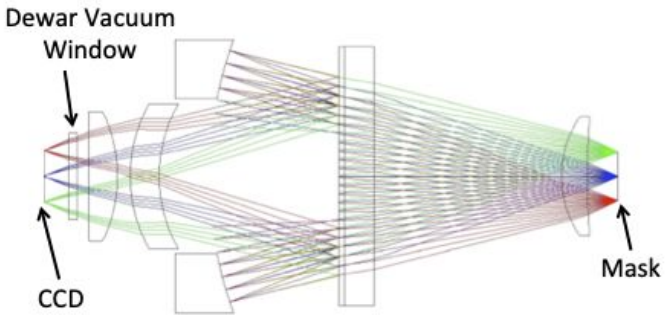
    c. Data Access
2. CCD Timing Adjustments
    a. General Electro-Optical Characterization
    b. Crosstalk Measurements
3. Persistence Testing

LSST Beam Simulator Overview



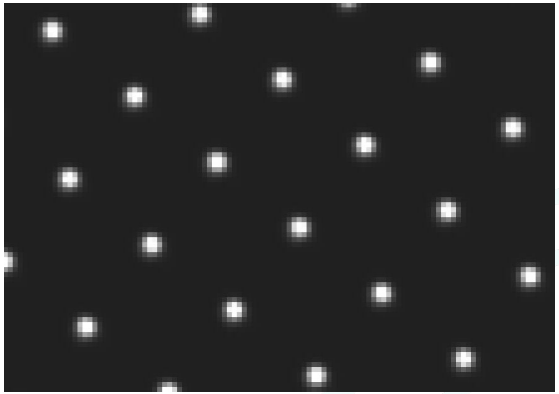


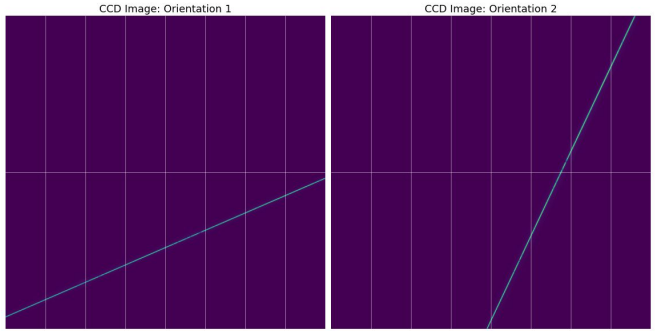
- Single LSST Camera CCD imaging system.
- Wide-field f/1.2 re-imaging optical system.
- Sci-in Tech PS-500 shutter blade shutter.
- Color filters: u, g, r, i, z, Y
- Photolithographic masks for realistic image projections (spot, streak, etc.).
- 3 axis stage for focusing and dithering.
- 0.4 micron resolution

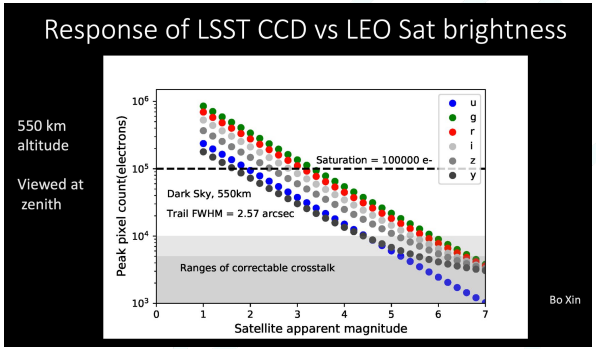
Full details: https://arxiv.org/abs/1411.5667

Past Studies

- CCD characterization using realistic images (https://arxiv.org/abs/1808.00534)
  - Brighter-fatter
  - Edge roll off
  - Deferred charge
- Crosstalk from satellite streaks (https://arxiv.org/abs/2006.12417)







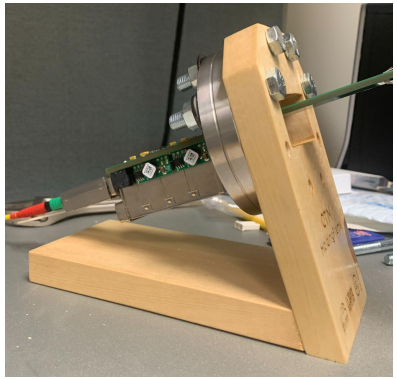
LSST Beam Simulator Upgrade

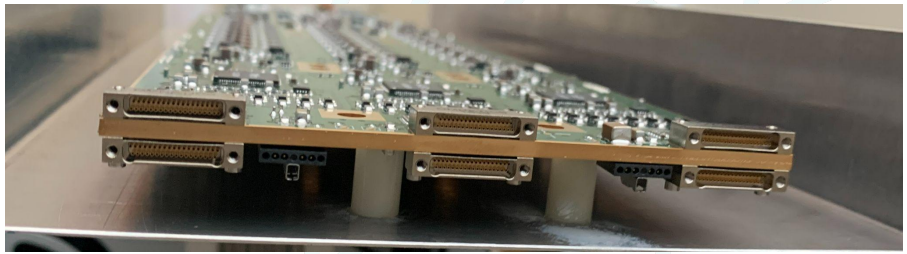
Hardware upgrades:

- DAQv4 “Darwin”
- Optical Transfer Module (OTM)
- REB5 (LCA-13574-102)

Currently installed: E2V-CCD250-112-09

Note: Our cable length is longer than LSSTCam.





DM Gen3 Instrument Implementation

LSST-UCDCam is an updated instrument definition in obs_lsst to allow for:

- Assembly of CCD images with appropriate geometry.
- Ingestion into a Gen3 Repository.
- Compatibility with existing DM Stack pipelines and analyses.

Gen3 Repo at USDF:
/sdf/group/rubin/repo/ucd

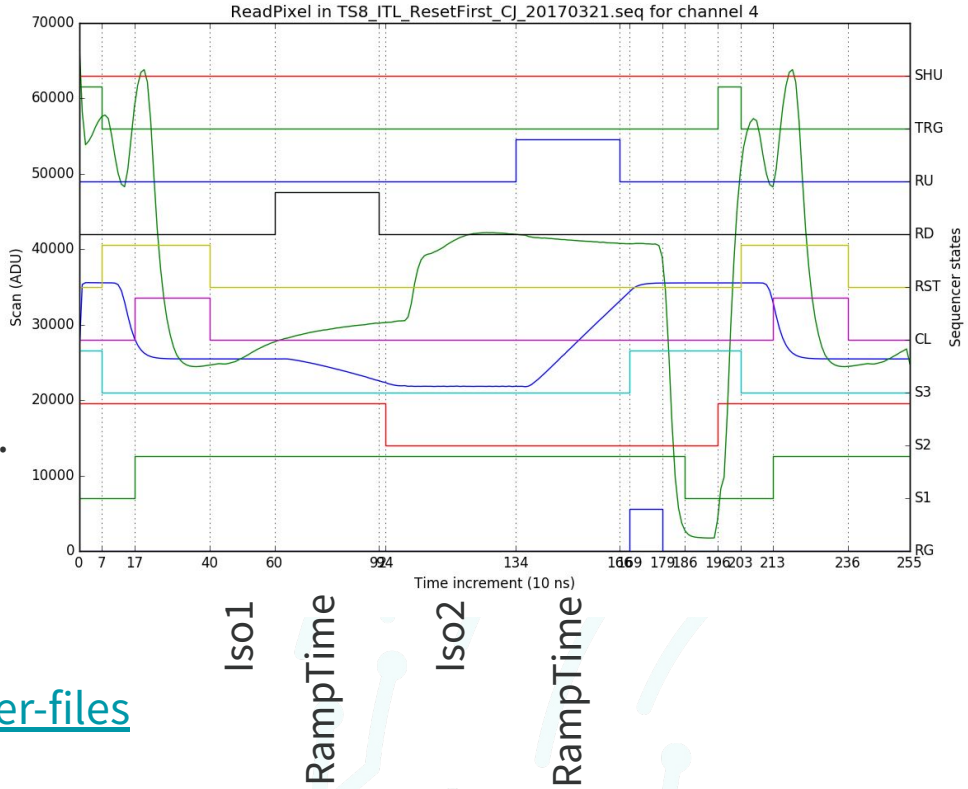
```
SIMPLE  =                    T / Java FITS: Thu May 04 12:46:42 PDT 2023
BITPIX  =                    8 / bits per data value
NAXIS   =                    0 / number of axes
EXTEND  =                    T / Extensions are permitted
DATE    = '2023-05-04T21:11:37.172' / Creation Date and Time of File
MJD     =    60068.88306912035 / Modified Julian Date that the file was written
CCD_MANU= 'ITL     '           / CCD Manufacturer
CCD_TYPE= '3800C   '           / CCD Model Number
TESTTYPE= 'SPOT' / BIAS, DARK, FE55, FLAT, LAMBDA, PERSISTENCE, SPOT, SFLAT_<lam
IMGTYPE = 'SPOT    '           / BIAS, DARK, FE55, FLAT, FLAT_<lam>, SPOT, PPUMP
DETSIZE = '[1:4072,1:4000]'
EXPTIME =                  2.0 / Exposure Time in Seconds
BINX    =                    1 / [pixels] binning along X axis
BINY    =                    1 / [pixels] binning along Y axis
CCDGAIN =                  1.0 / Rough guess at overall system gain (e-/DNB)
CCDNOISE=                 10.0 / Rough guess at system noise (e- rms)
DATE-OBS= '2023-05-04T21:11:37.170' / Date of the image trigger (readout), UTC f
MJD-OBS =  60068.883069097064 / Modified Julian Date of image trigger
DATE-TRG= '2023-05-04T21:11:37.170' / Date of the image trigger (readout), UTC f
MJD-TRG =  60068.883069097064 / Modified Julian Date of image trigger
IMAGETAG= 'b9e854d81d7540ca'   / DAQ Image id (Hex)
CCDSLOT = 'S01     '           / The CCD Slot
RAFTBAY = 'R22     '           / The RAFT Bay
FIRMWARE= '3139500d'           / DAQ firmware version (Hex)
PLATFORM= 'darwin  '           / DAQ platform version
CONTNUM = '18eda94e'           / REB serial # (Hex)
DAQVERS = 'R4-V4.14 2022-04-05T21:12:15Z (2af7b01b)' / DAQ version
DAQPART = 'davis   '           / DAQ partition
DAQFOLD = 'raw     '           / DAQ folder the image was initially created in
DAQANNOT= '        '           / DAQ image annotation
OBSID   = 'TS_C_20230504_000016' / The image name or obs-id
TELCODE = 'TS      '           / The "code" for AuxTel | ComCam | Main Camera
CONTRLLR= 'C       '           / The controller (e.g. O for OCS, C for CCS)
DAYOBS  = '20230504'          / The observation day as defined in the image name
SEQNUM  =                   16 / The sequence number from the image name
HEADVER =                    2 / Version number of header
INSTRUME= 'LSST-UCDCam-ITL'    / Instrument
TELESCOP= 'LSST    '           / Telescope
TSTAND  = 'LSST_Beam_Simulator' / Camera test stand BOT or CCOB
SEQFILE = 'FP_ITL_2s_ir2_v26.seq' / Sequencer file name
SEQCKSUM= '980618532'          / Checksum of Sequencer
LSST_NUM= 'ITL-3800C-002'      / LSST Assigned CCD Number
CCD_SERN= 'Unknown '           / Manufacturers? CCD Serial Number
REBNAME = 'LCA-13574-102'      / LSST Assigned Name REB name
RAFTNAME= 'LCA-11021_RTM-ITL-22' / LSST Assigned Raft name
DARKTIME=               3.0981 / Dark Time in Seconds (see TSEIA-91)
FPVERS  = '1.1.1   '           / The focal-plane version number
IHVERS  = '1.0.28  '           / The image-handling version number
CHECKSUM= 'nDUenDTbnDTbnDTb'   / checksum for the current HDU
DATASUM = '0       '           / checksum of the data records
```

Sequencer Timing Adjustments

Timing adjustments made to:

- Iso1
- Iso2
- Ramp Time (RU/RD)
- Invert Count (pre-integration)

Readout set using a SEQ file (nominal is v26).



https://github.com/lsst-camera-dh/sequencer-files

Electro-Optical Characterization

DM Calibration Datasets:

- Bias
- Dark
- Flat
- Defects
- PTC

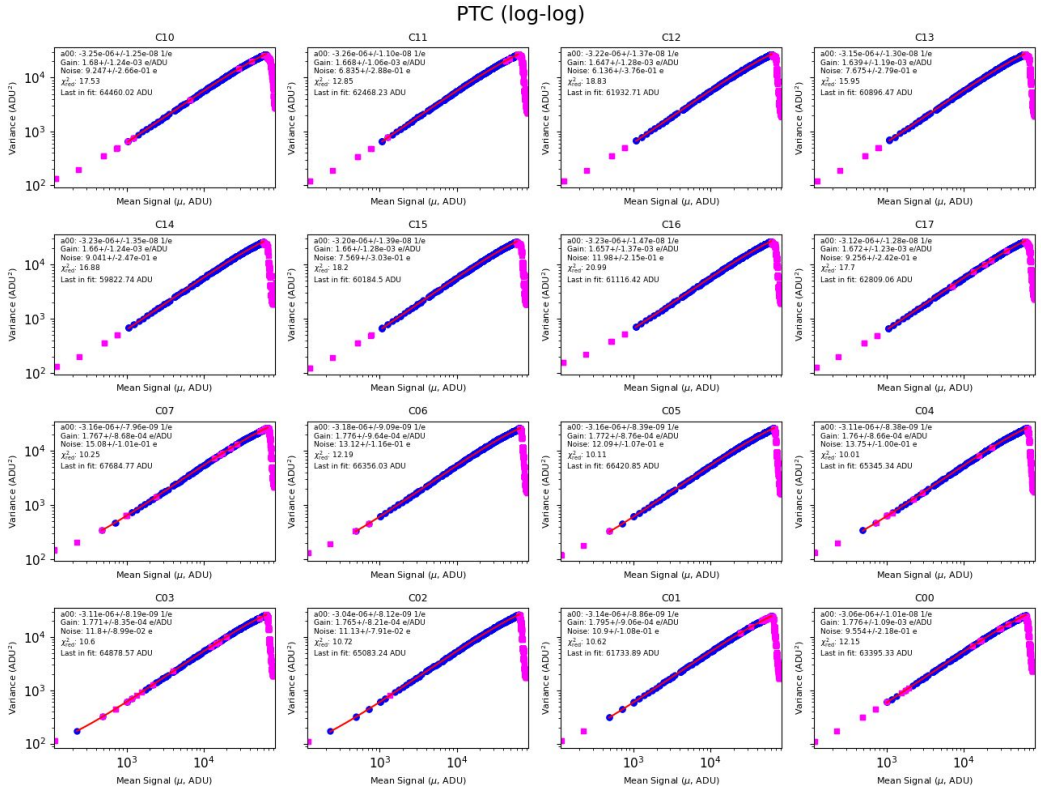
Pipetasks:
https://github.com/lsst/cp_pipe

EO Measurements

- Read noise (12 e-/sec/pixel)
- Dark current (0.02 e-/sec/pixel)
- Divisadero tearing
- Brighter-fatter
- Crosstalk (order of 10^-3)
- Persistence

Pipetasks:
https://github.com/lsst-camera-dh/eo_pipe

PTC Curves



PTC curves from flat pairs to calculate gain, read noise, and full well.

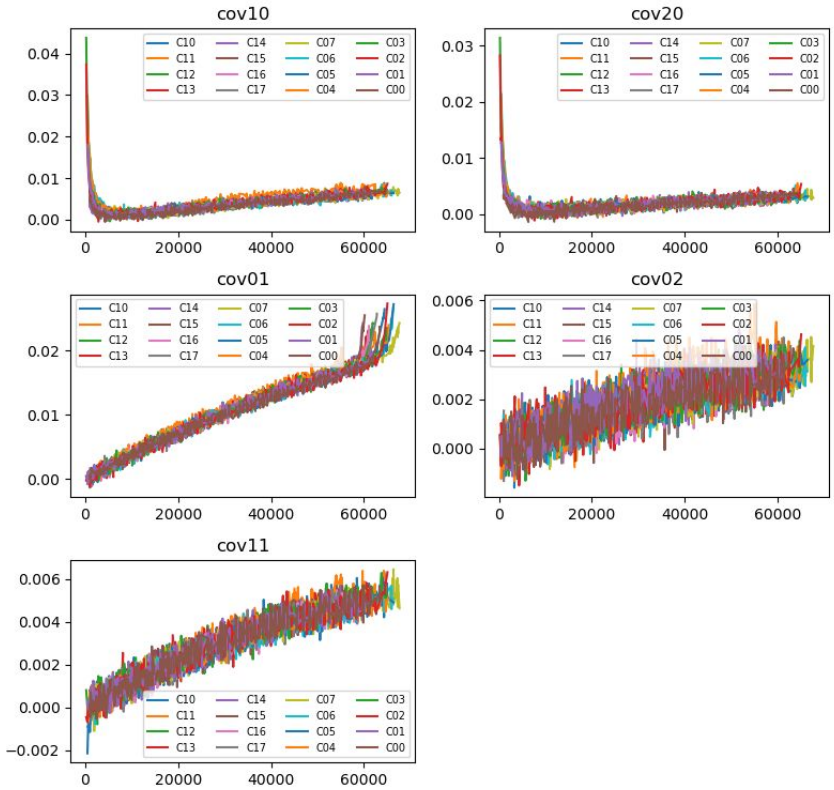
Pipeline: cpPtc

Brighter-Fatter

Brighter-fatter statistics are calculated from the PTC curves.

Plots of the covariance matrix elements C_ij vs signal are a standard data product, from which the BF kernel can be generated.

Pipeline: eoBFAnalysis

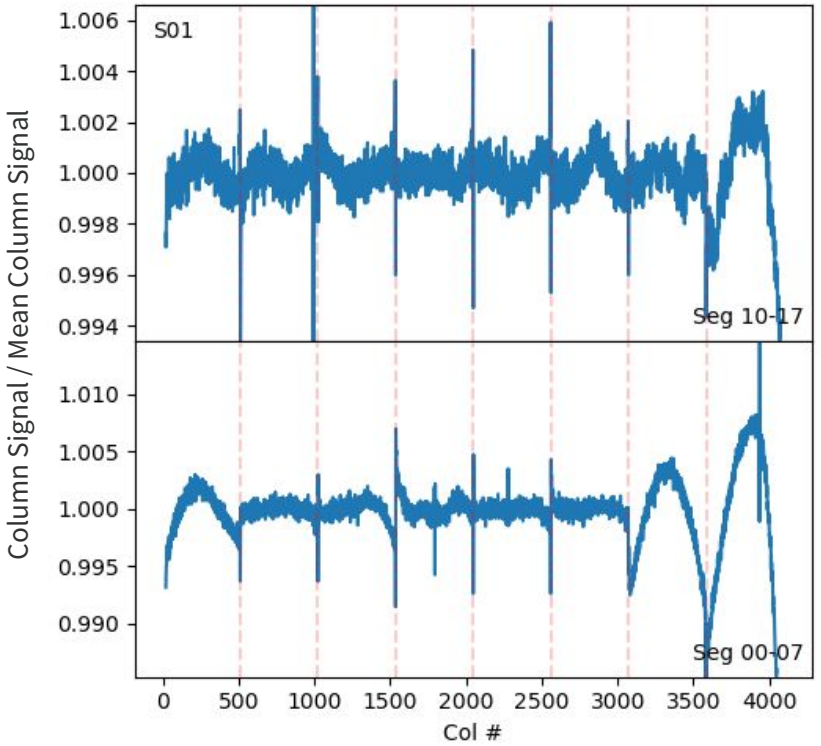


Divisadero Tearing

Divisadero tearing refers to large signal variations at amplifier boundaries.

Measure the column signal to mean column signal from flat fields to quantify the amplitude of the effect.

Pipeline: eoDivisaderoTearing



EO Summary

Increased Ramp Time:

- Decreased gain (e-/ADU) and read noise.
- Slightly lower divisadero tearing amplitude.

Increased Iso1 and Iso2

- Small decrease in read noise

Increased Invert Count:

- No substantial change to divisadero tearing amplitude.

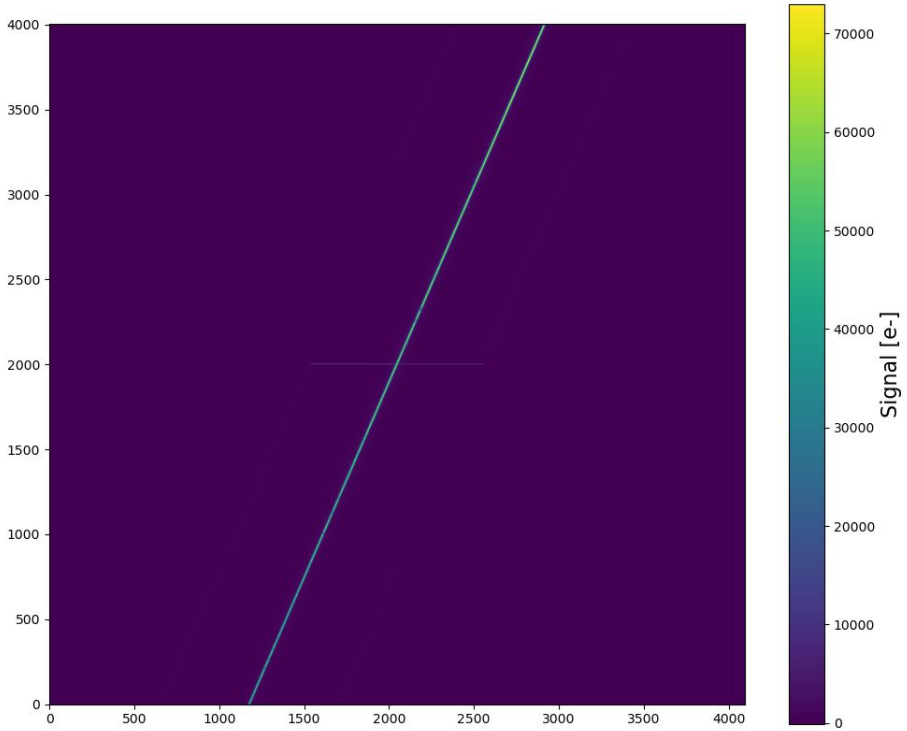
Concluded that only minor improvements to general EO properties at the expense of longer readout times.

Crosstalk Characterization

We acquired a series of streak images at a range of brightness levels.

Use a model fit methodology to get:

- Linear crosstalk term
- First-order nonlinear crosstalk term
- Background terms

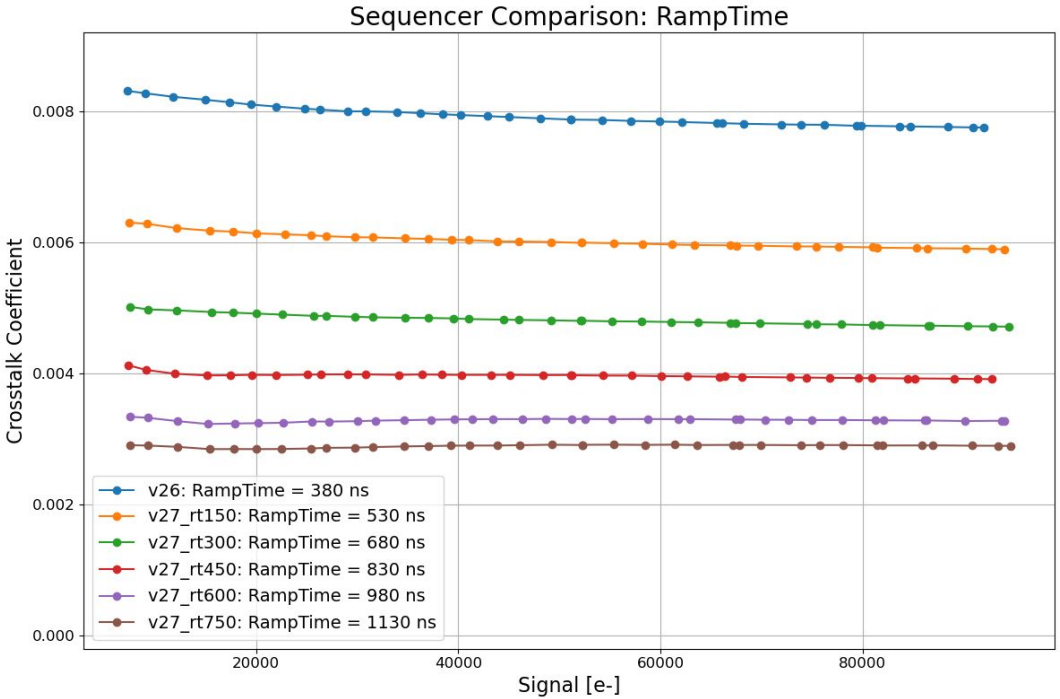


Crosstalk Characterization: RampTime

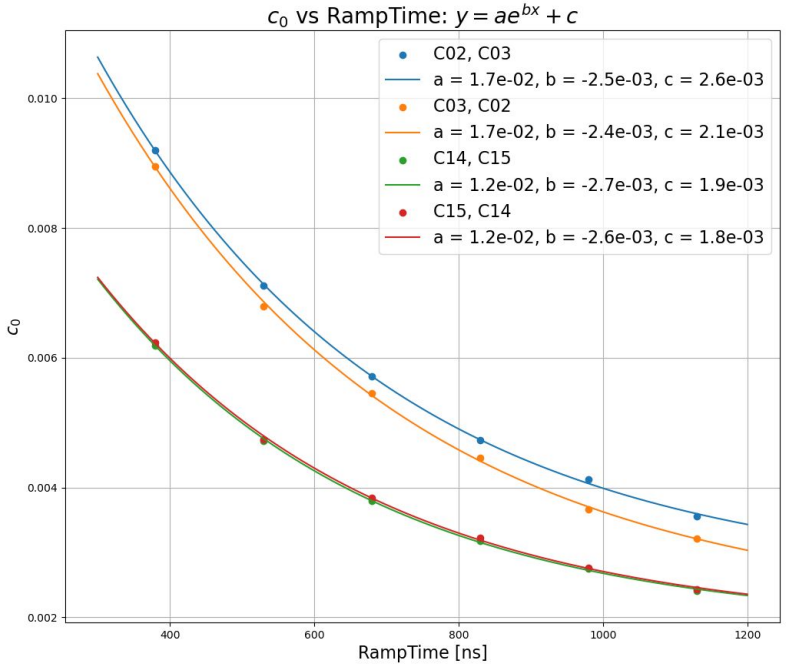
Settings:

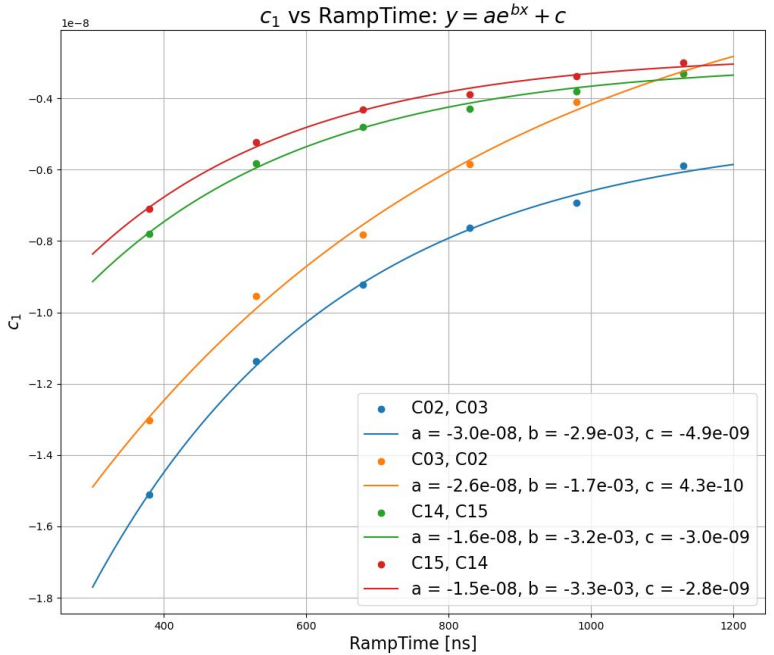
- Iso1 = 130 ns (nominal)
- Iso2 = 320 (nominal)
- RampTime increased from 380 ns (nominal) in steps of 150 ns.
- Invert Count = 3000 ns (nominal)

Increasing the Ramp Up/Down time has a significant effect on decreasing the crosstalk.



Crosstalk Characterization: RampTime





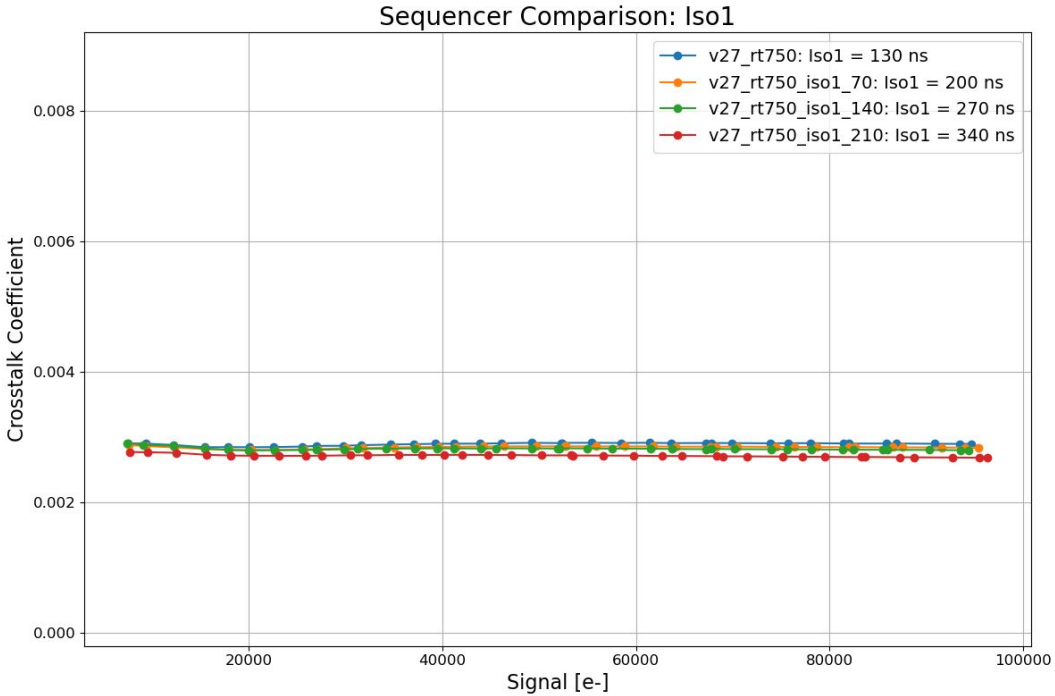
Increased ramp time decreases both the linear and non-linear crosstalk (4 amp pairs shown).

Crosstalk Characterization: Iso1

Settings:

- Iso1 increased from 130 ns (nominal) in steps of 70 ns
- Iso2 = 320 ns (nominal)
- RampTime = 1130 ns
- Invert Count = 3000 ns (nominal)

There was minimal impact on the crosstalk due to changes to Iso1.

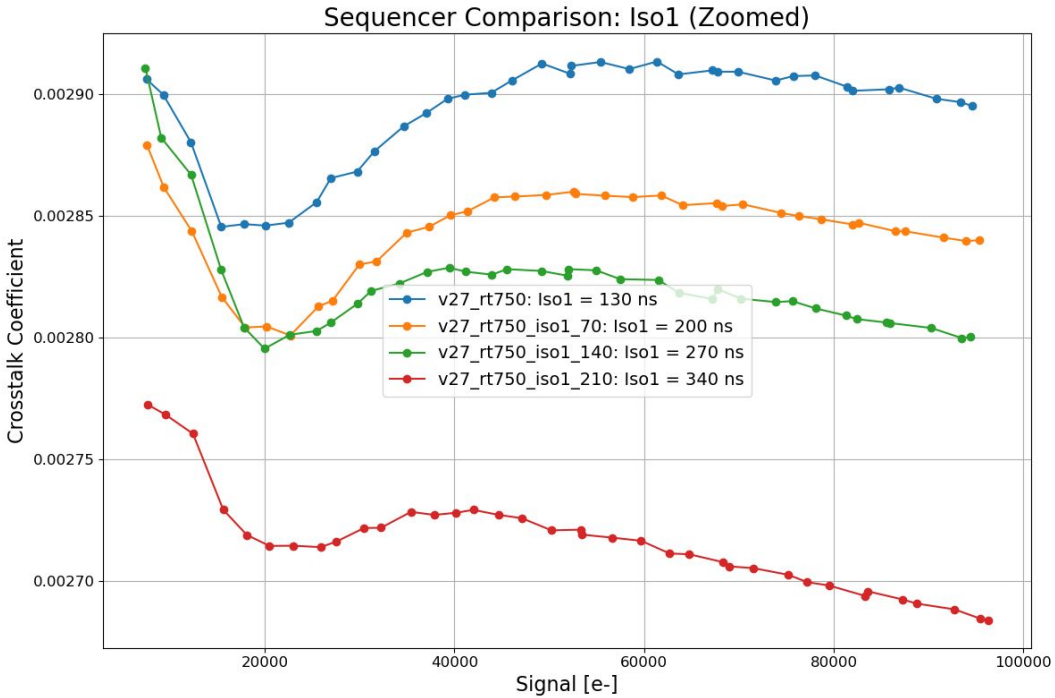


Crosstalk Characterization: Iso1 (Zoomed)

Settings:

- Iso1 increased from 130 ns (nominal) in steps of 70 ns
- Iso2 = 320 ns (nominal)
- RampTime = 1130 ns
- Invert Count = 3000 ns (nominal)

There was minimal impact on the crosstalk due to changes to Iso1.

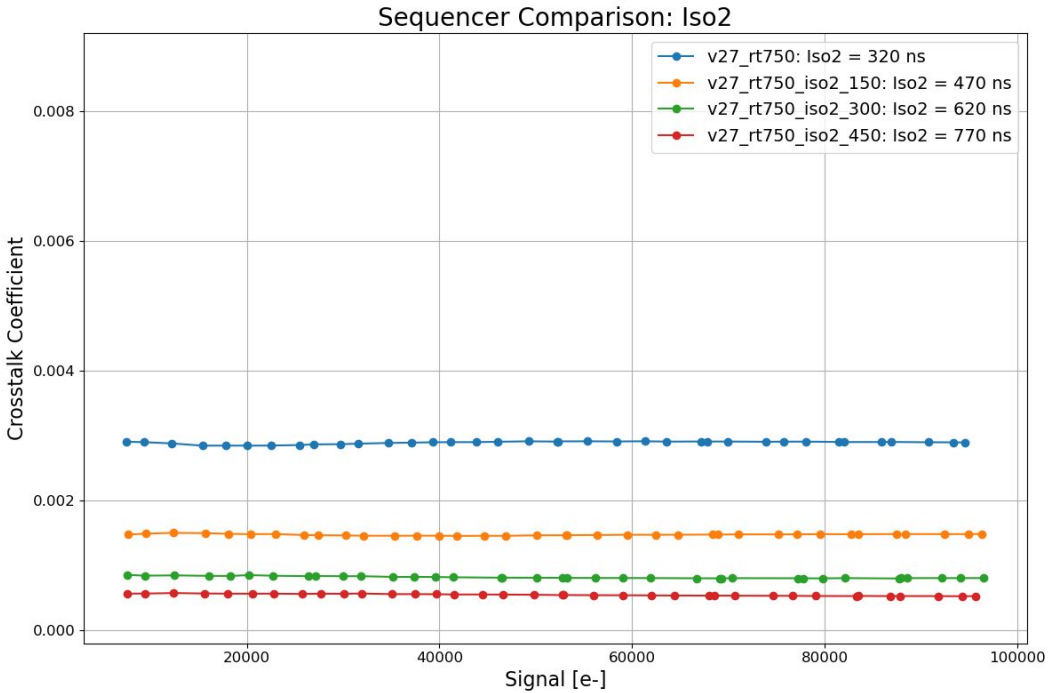


Crosstalk Characterization: Iso2

Settings:

- Iso1 = 130 ns (nominal)
- Iso2 increased from 320 ns (nominal) in steps of 150 ns.
- RampTime = 1130 ns
- Invert Count = 3000 ns (nominal)

By increasing Iso2 the crosstalk was further reduced.

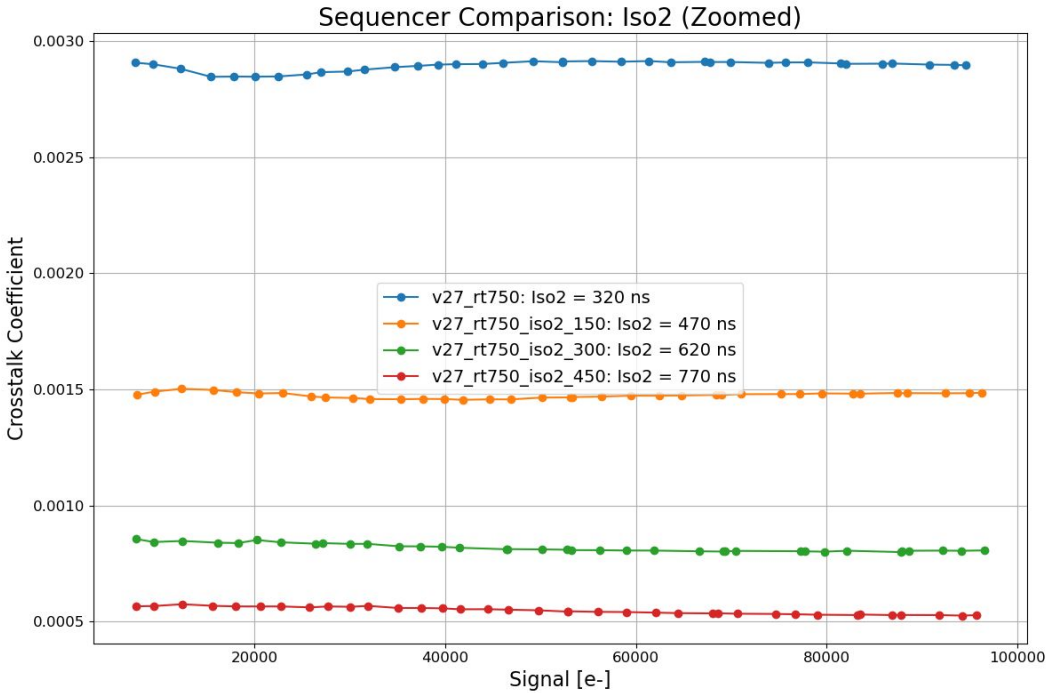


Crosstalk Characterization: Iso2 (Zoomed)

Settings:

- Iso1 = 130 ns (nominal)
- Iso2 increased from 320 ns (nominal) in steps of 150 ns.
- RampTime = 1130 ns
- Invert Count = 3000 ns (nominal)

By increasing Iso2 the crosstalk was further reduced.

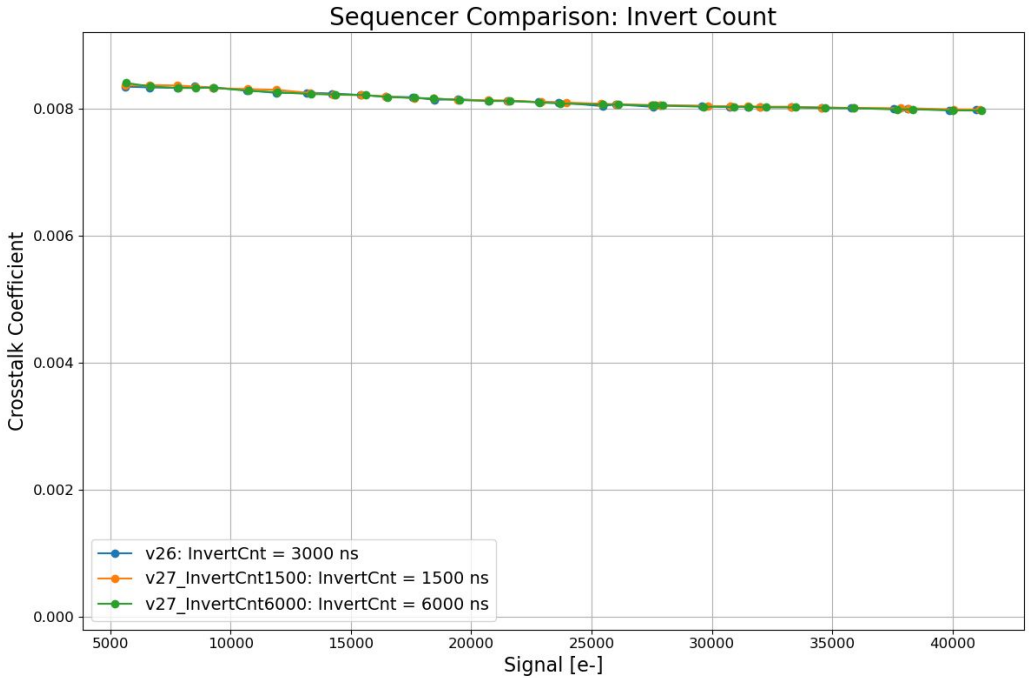


Crosstalk Characterization: Invert Count

Settings:

- Iso1 = 130 ns (nominal)
- Iso2 = 320 ns (nominal)
- RampTime = 380 ns (nominal)
- Invert Count = 1500, 3000, 6000 ns

As expected changing the invert count, which is inversion of the parallel clocks before integration, did not affect the crosstalk.

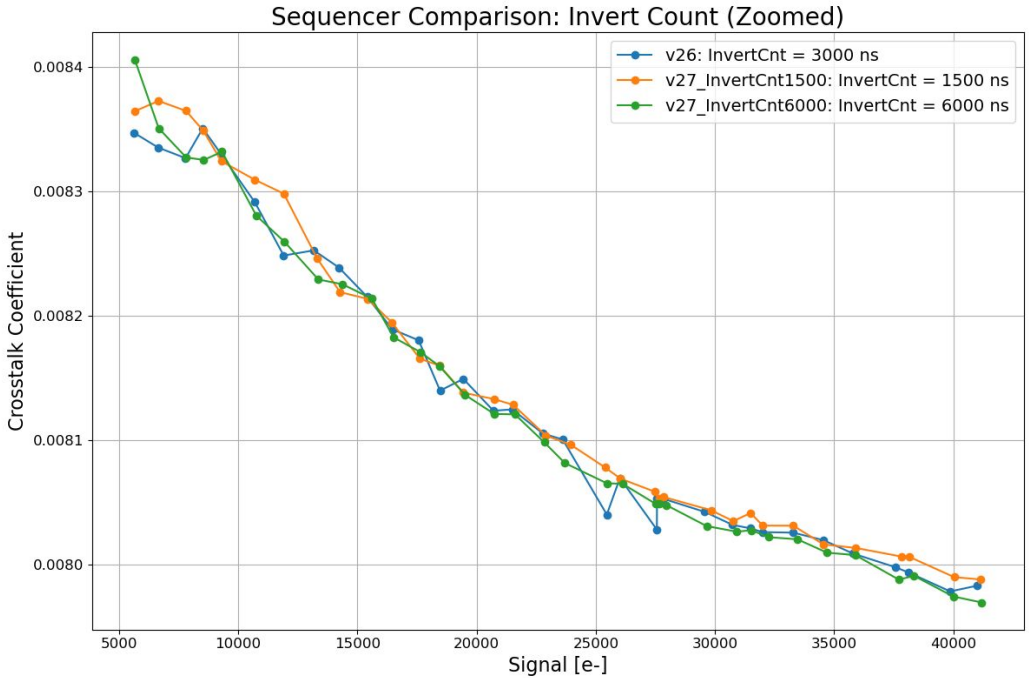


Crosstalk Characterization: Invert Count (Zoomed)

Settings:

- Iso1 = 130 ns (nominal)
- Iso2 = 320 ns (nominal)
- RampTime = 380 ns (nominal)
- Invert Count = 1500, 3000, 6000 ns

As expected changing the invert count, which is inversion of the parallel clocks before integration, did not affect the crosstalk.

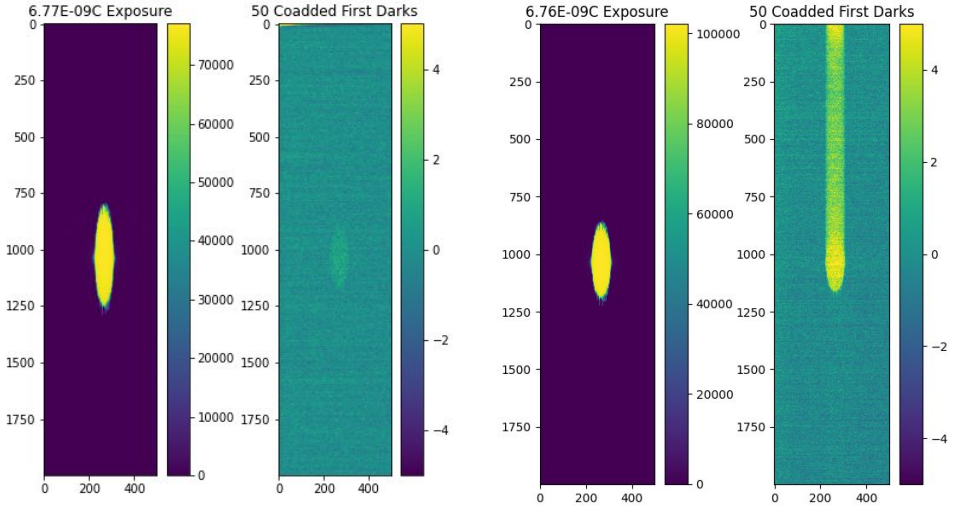


Crosstalk Summary

Possible improvements to the linear and nonlinear crosstalk can be accomplished by increasing ramp time or Iso1.

It is recommended that future timing changes should adjust Iso2, in order to minimize the readout time increases.

Persistence



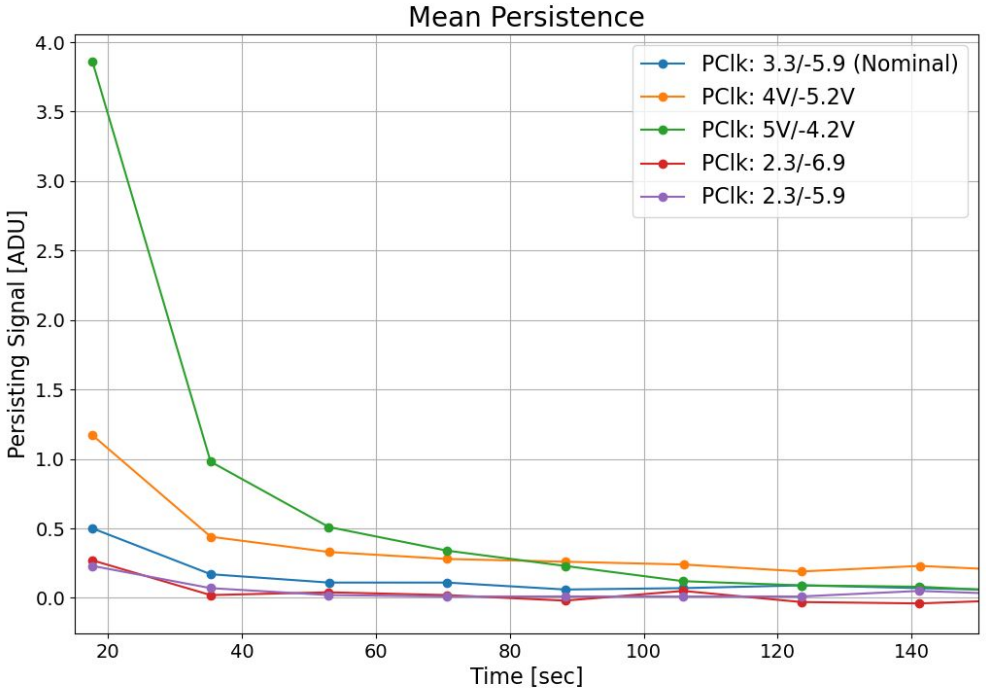
Teledyne e2v CCDs exhibit persistence following bright exposures. This is not observed in ITL CCDs.

The amplitude of persistence varies amongst CCDs. For nominal voltages our CCD shows very little persistence.

Persistence Summary

We can lower the persistence by decreasing Pclk High or decreasing Pclk Low.

We plan to do a general electro-optical characterization to determine the impact of changes to the clock voltages.



Conclusion

1. General improvements to EO properties with slower readout.
   a. Changes likely outweighed by the increased read out time.
2. Improvements to crosstalk can be obtained with longer Iso2 and Ramp Time.
   a. Preferable to only adjust Iso2.
3. Possible improvements to persistence in Teledyne e2v sensors by adjusting the serial clock voltages.
   a. Follow up studies necessary before making operational changes.

Acknowledgements

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