Direct Signal Injection Crosstalk in LSST Camera Readout Electronics

Origins of Crosstalk Nonlinearity

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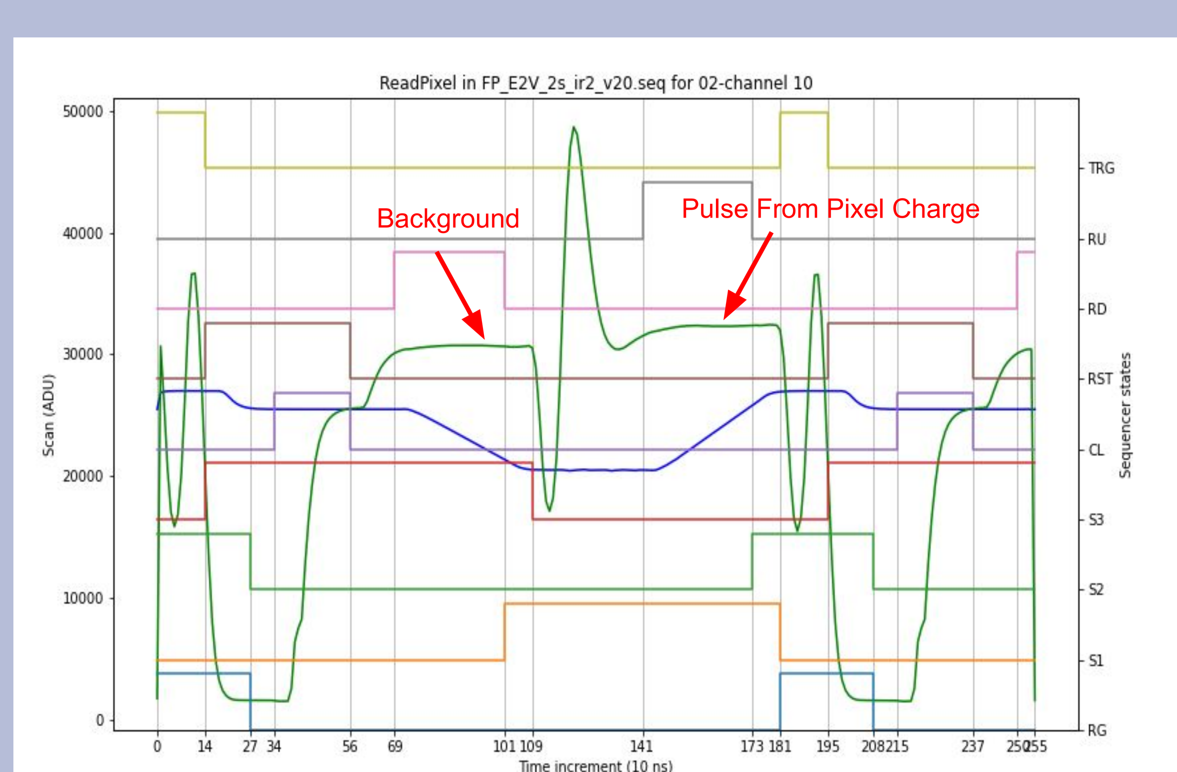
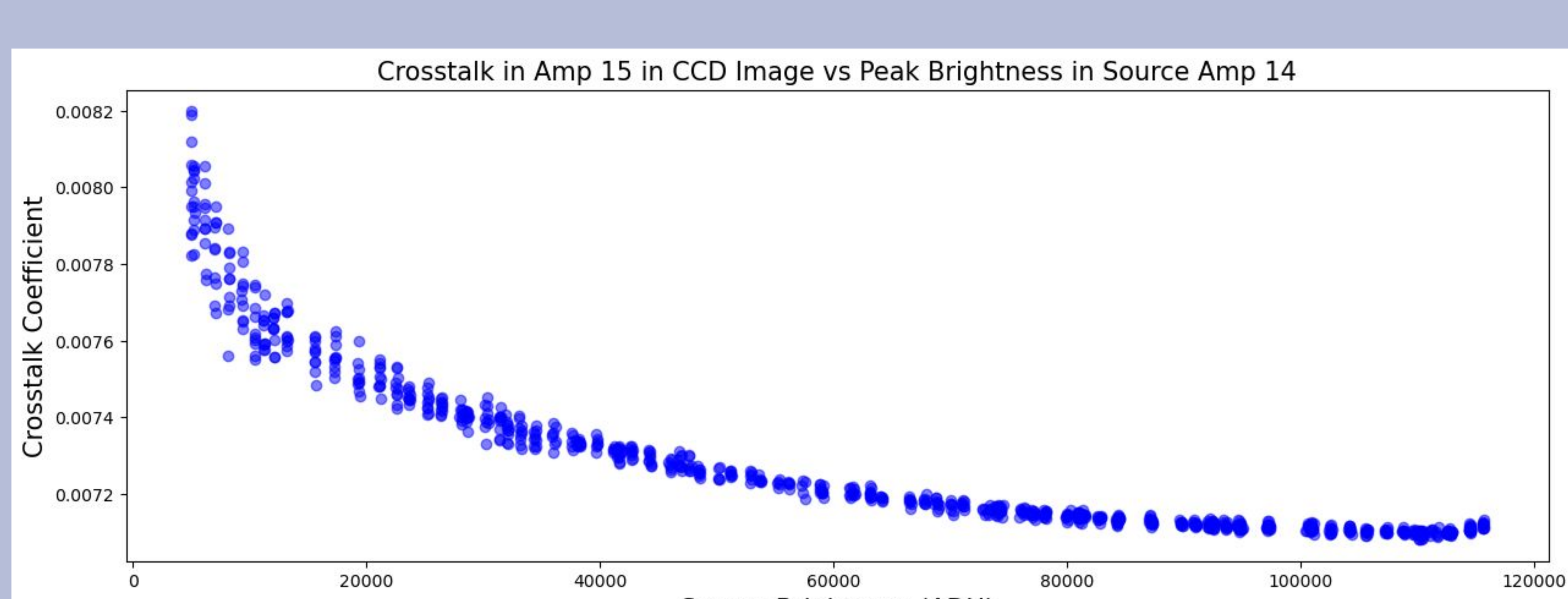
The CCDs in the Rubin LSST camera exhibit novel nonlinear crosstalk between amplifier segments. But how much of this crosstalk nonlinearity comes from the CCD, and how much comes from the REB5 electronics? We built a PCB that simulates the capacitive and resistive load of the CCD which we use to probe clocks or inject signals into video readout channels. This video feeds the LSST readout electronics board (REB5), which is identical to those used in the main LSST Camera.

Crosstalk with Readout Electronics + CCD

Crosstalk. An image from the UCD LSST Test Lab[1] simulating a satellite streak crossing four CCD segments. This produces a bright streak where the satellite would pass, but also an echoing crosstalk signal in the nearest amplifier segment, and in farther amplifiers. There are 16 segments on a CCD divided into two 8-amplifier sides. Each segment's amplifier can crosstalk to other amplifiers, with coefficients *Cij*.



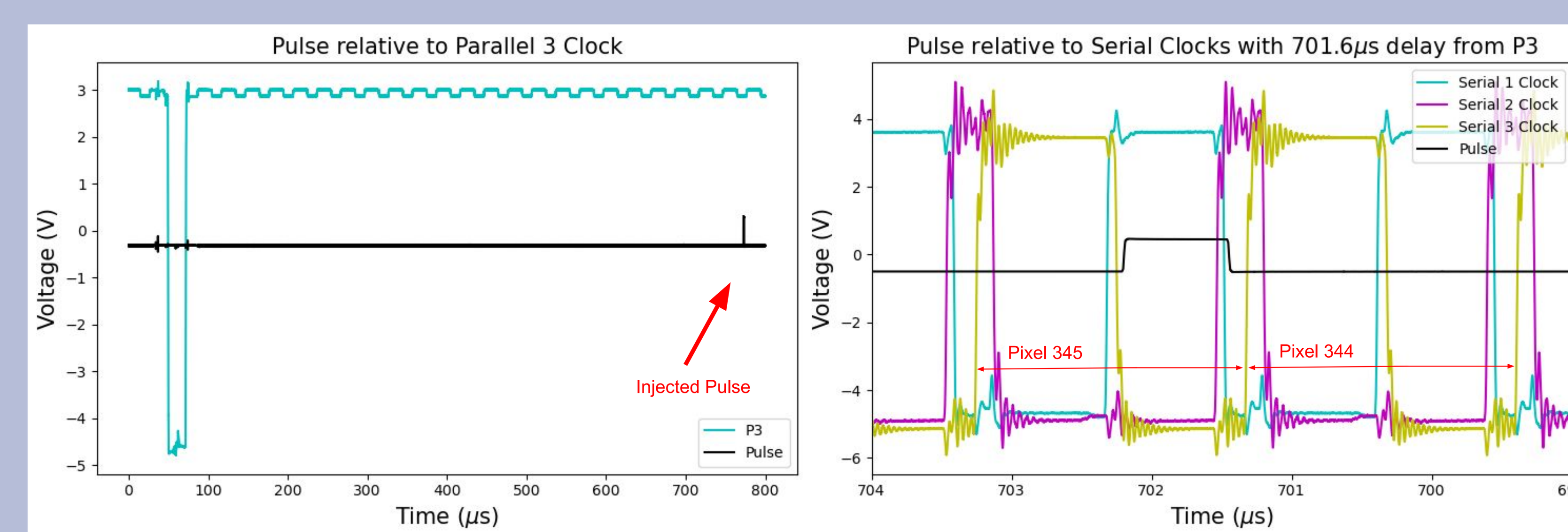
The true CCD video signal (Green) and correlated double sampler (Blue), shown in comparison to various clock timings. Here we show the true relative pulse location in phase with the camera readout.



The ratio between source and crosstalk pixel values as a function of peak pixel brightness with the CCD. Notably, the ratio varies as a function of signal level implying that the crosstalk does not come from capacitive coupling alone. This crosstalk may originate from either the readout electronics, the CCD, or both. Crosstalk can be modeled with a three parameter fit.

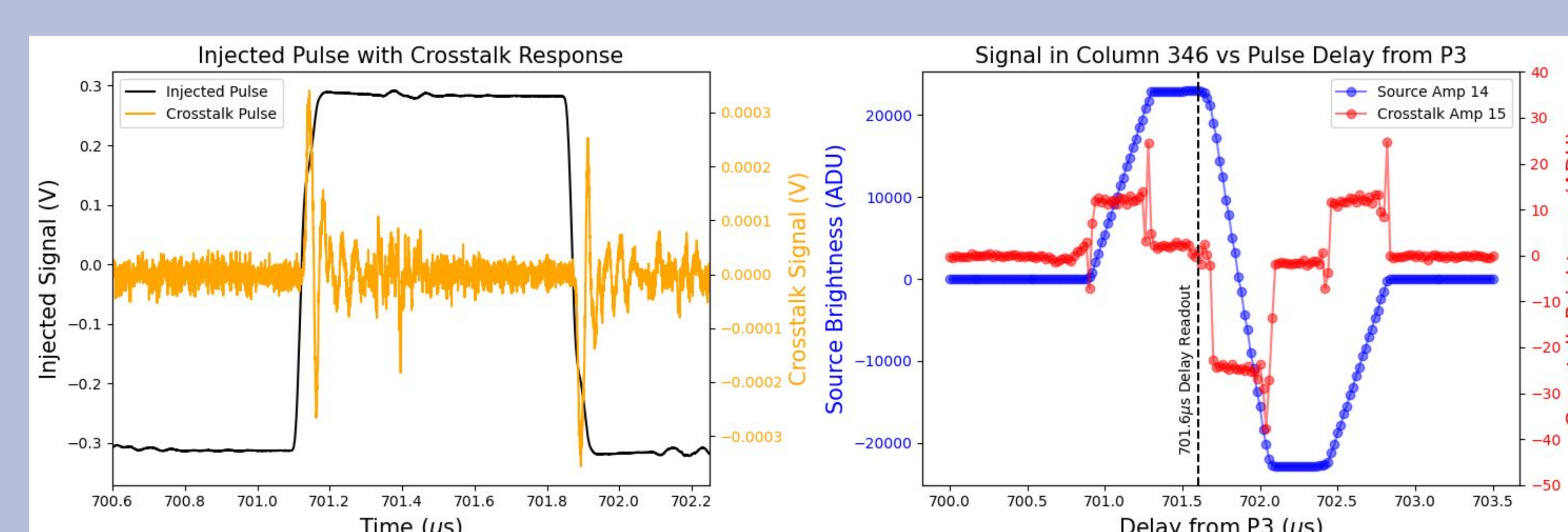
Crosstalk in Readout Electronics Without CCD

By injecting a square wave to simulate the video signal in our CCD directly into the CCD using our injection board, we can bypass the CCD and study crosstalk in the readout electronics directly compared to the CCD.



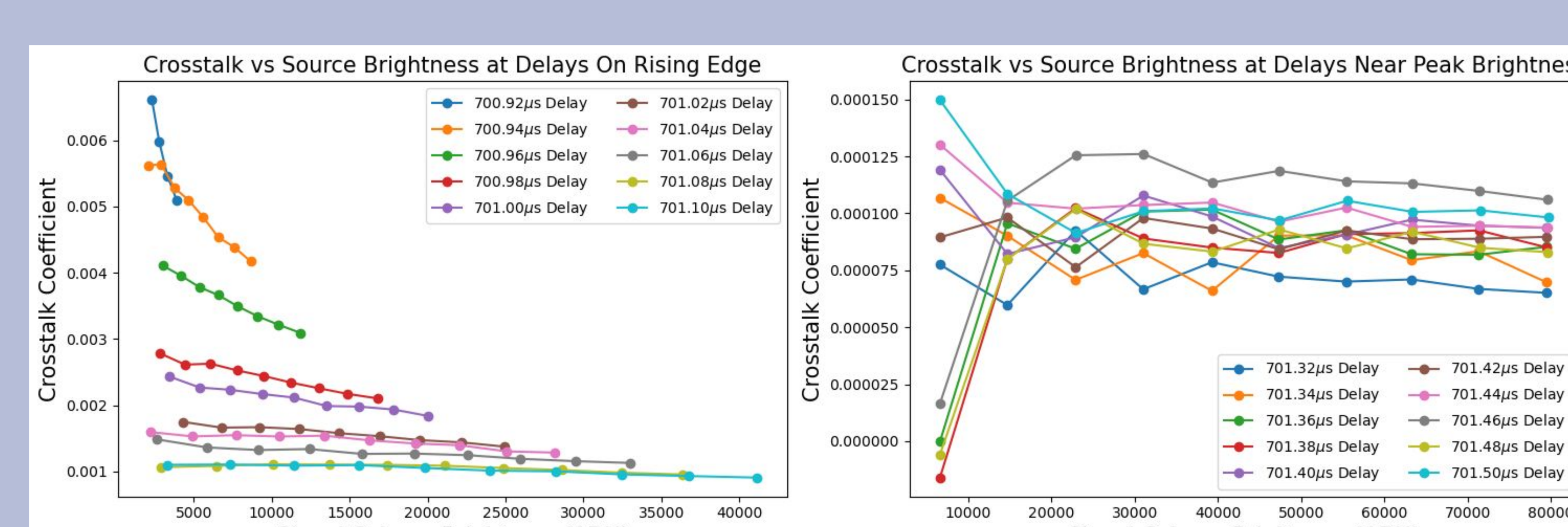
The injected pulse relative to the 3rd parallel clock (P3). We trigger the injected pulse on the parallel clocks which makes the pulse in the same place in every row. We then use these similarly affected columns in our analysis. By changing the delay of the pulse relative to P3 we can change which pixels are affected.

The injected pulse relative to the serial clocks with a 701.4μs delay from the P3 trigger. We can shift the injected pulse on a sub pixel readout level. By reading out source and crosstalk images while tracing through the delay, we can study the phase of the crosstalk signal relative to the readout electronics.



Oscilloscope readouts of the injected pulse in amplifier 14 and the response crosstalk pulse in amplifier 15. The maximum signal is down by a factor of a hundred. However, the crosstalk signal is also out of phase with the pixel readout which further lowers the crosstalk brightness in images.

Average readout of pixels a column in amplifier 14 (where we inject the pulse) and amplifier 15 (the nearest neighbor amp where we measure crosstalk). Sweeping through delays from P3, the readout electronics responds.. Here we change the relative timing to show the effect of crosstalk being out of phase with readout.



The ratios between source and crosstalk (Amp 14 to Amp 15) pixel values as a function of source brightness with injected signals. Here we show varying pulse delays near the in phase signal position for the camera readout. The two plots are two different regions of delay space. On the left are delays on the rising pulse readout. Here a small change in delay drastically changes the crosstalk linearity. On the right we show delays near the peak signal readout. Here the crosstalk still falls off nonlinearly on a much smaller scale.

We conclude that much of the nonlinearity may arise from the readout electronics (REB5).

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References:

[1] Tyson, et al. *LSST Optical Beam Simulator,* in High Energy, Optical, and Infrared Detectors for Astronomy VI, Proc. SPIE 9154, 350 (2014), arXiv:1411.5667

[2] Juramy, et al. *Driving a CCD with two ASICs: CABAC and ASPIC* in High Energy, Optical, and Infrared Detectors for Astronomy VI Vol. 9154. SPIE, 2014.

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