Digital Correlated Double Sampling for ZTF

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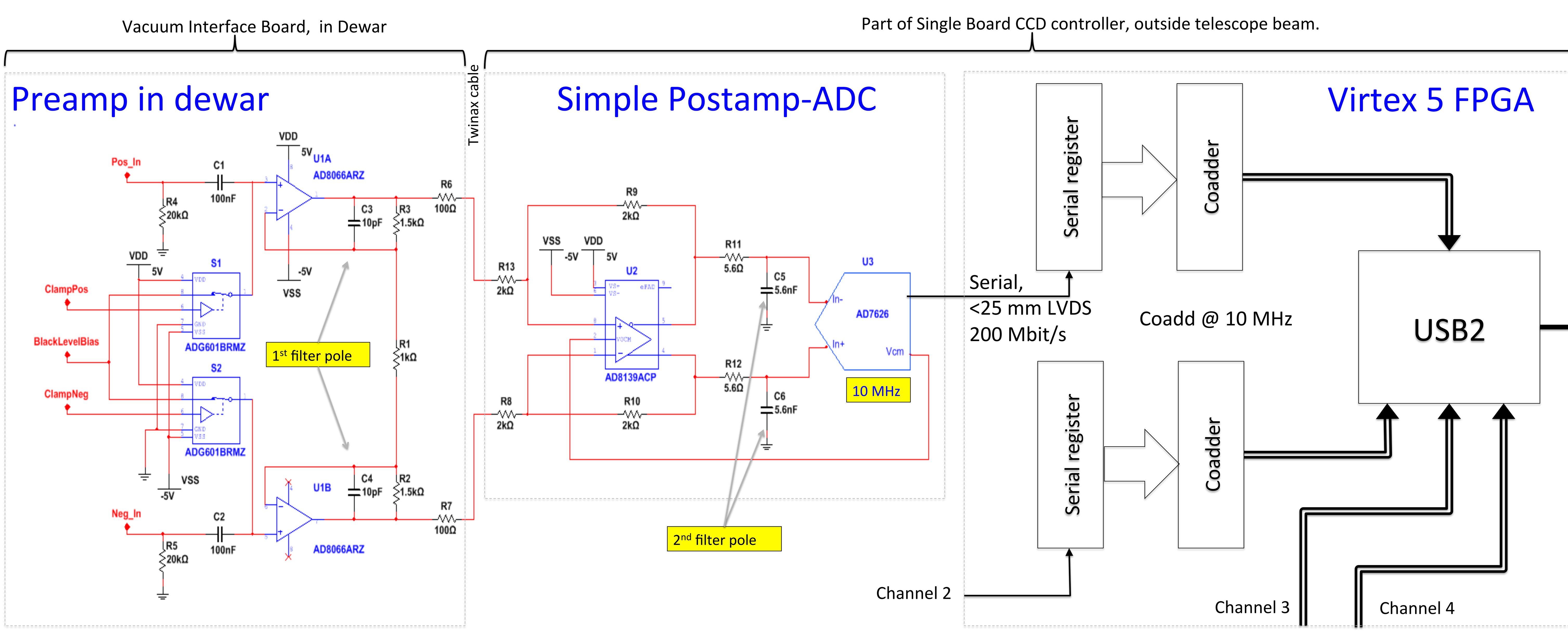
Advantages of Digital CDS

- Simplicity, compactness: see circuit below.
- Faster than normal rates possible, albeit with higher noise. Maximum is set by antialiasing filter corner.
- Slower pixel rates use same analog gain and BW. Just do more coadds → noise and dynamic range improve automatically. Contrast with…
  - Clamp-sample needs different filter BW.
  - Dual slope needs gain (integrator capacitor) change.
- Dynamic range exceeds ADC's, thanks to averaging.
- No tuning to match true and inverse gains: only one path.
- True zero: offsets are removed perfectly by subtraction. Unipolar ADC produces bipolar data after subtraction.
- Digital oscilloscope mode: can transmit all samples to show raw video waveform instead of coadding (usually on subset of video channels to avoid overwhelming data link).

The digital equivalent of dual slope integration is to subtract N samples after the CCD reset from the sum of N samples after the charge dump. For sufficient sample density, and with a suitable antialiasing filter, the transfer function for digital CDS approaches the dual slope integrator. ***The key question is how low can the sample density be without significantly compromising read noise.***

Zwicky Transient Facility (ZTF) camera's pixel rate is 1 MHz. We would like to use the AD7626 charge division ADC since it delivers excellent DNL (±0.35ADU), low noise (<0.5ADU) with 16 bit resolution at low power (136mW) in a compact (25 mm²) package, however its conversion rate is only 10 MHz.

We present the transfer functions at low sample density to show that averaging only 5+5 samples at 10MHz comes within 1% of the dual slope integrator's read noise when a 2 pole anti-alias filter with 4MHz corner frequency is used. This moderate-sample-rate CDS processor with uncompromised ADC performance is very simple and compact with low power consumption, as needed in high channel count cameras. At the same time it will deliver greater than 16 bit dynamic range with superb DNL.



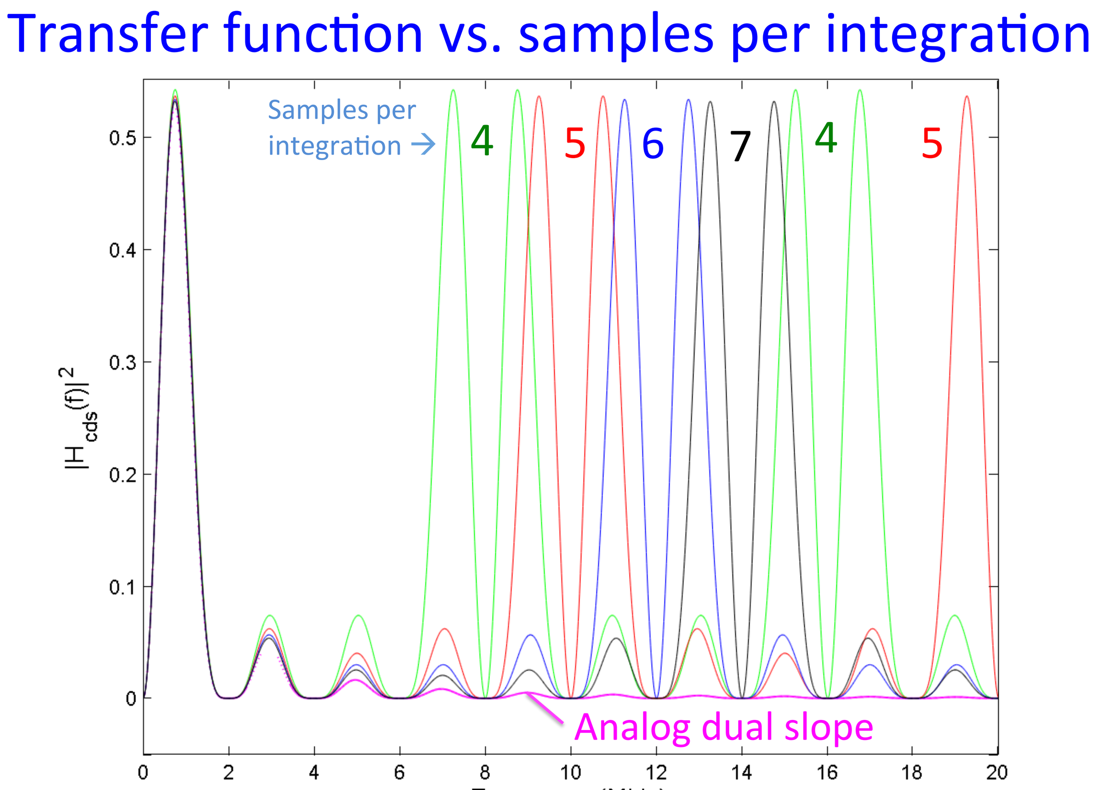
Digital CDS produces >17 bits of dynamic range. Extend to 32 bits so that data stored in RAM does not have to be unpacked before disk write in FITS Tile Compression format. This uses lossless Rice compression on pixel data and leaves headers uncompressed.

Commercial fiber optic USB extender.

4ch * 1 Mpixel/s * 32 bit = 128 mbit/s

USB2 is rated at 400mbit/s.

Transfer function vs. samples per integration



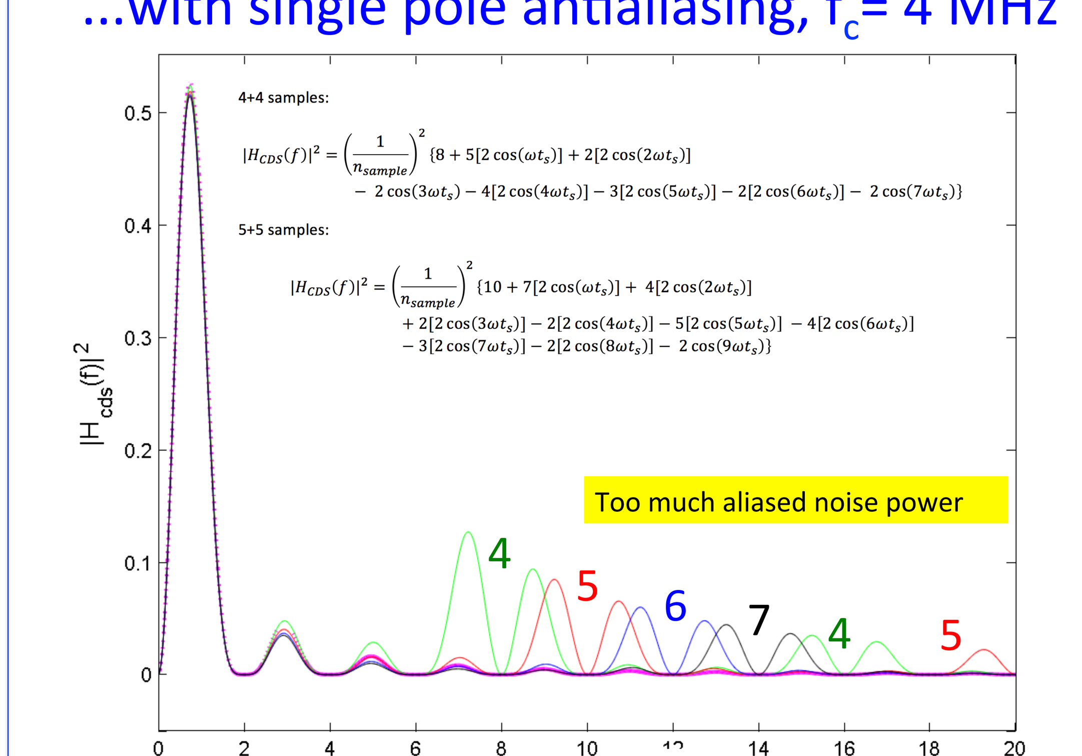
Transfer functions for various sampling densities are compared with the classic dual slope integrator. Total integration time is constant.

The dual slope integrator's base-band response is replicated well, even for low sample density.

The digital CDS has additional passbands on the high side of Nyquist frequency. These admit noise unless filtered.

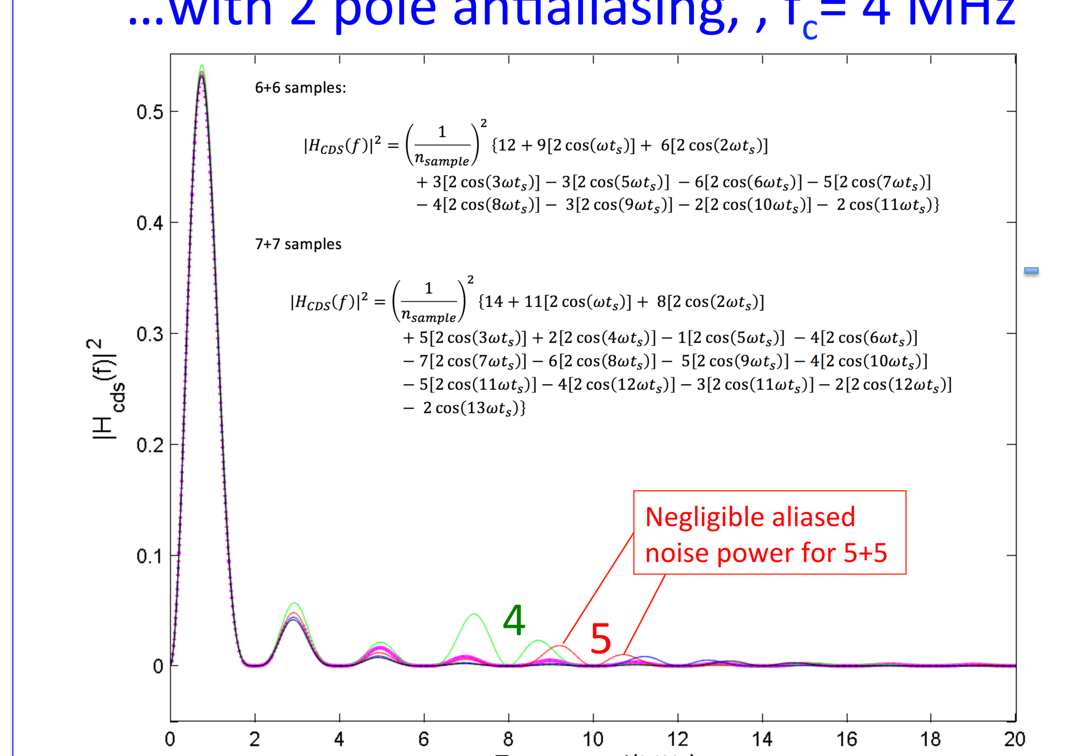
At low sample count per integration, the aliases occur closer to the signal passband requiring an antialiasing filter with steeper roll off.

…with single pole antialiasing, f_c= 4 MHz

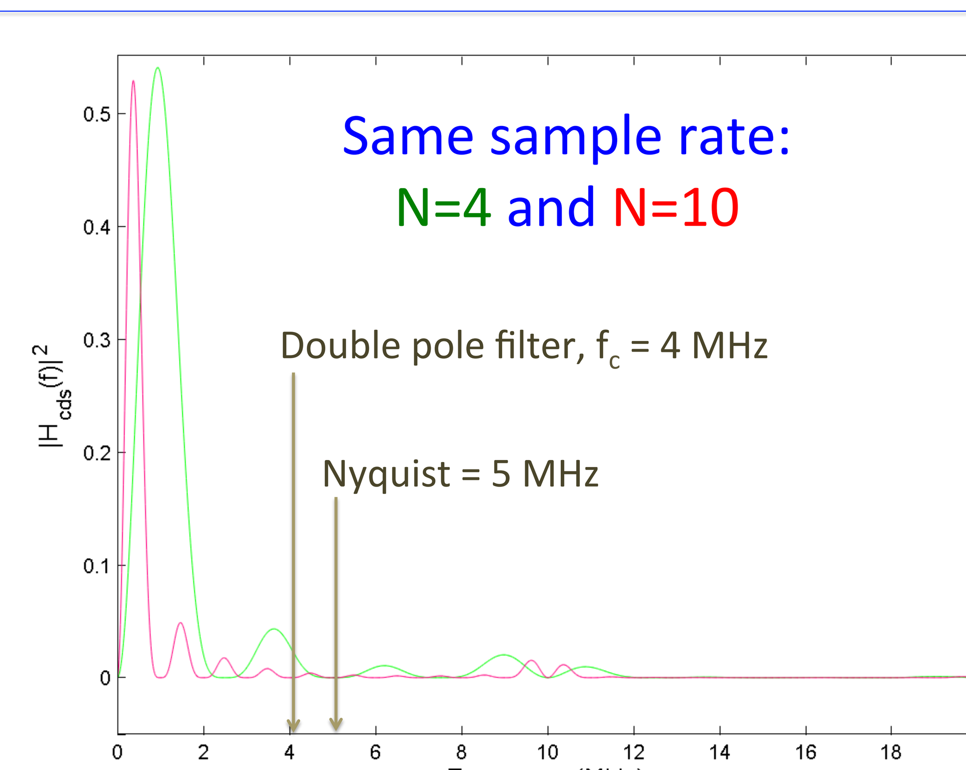


The transfer functions have been multiplied by a single pole filter at 4 MHz. Aliased power for 5+5 samples → noise 14% above dual slope.

…with 2 pole antialiasing, , f_c= 4 MHz



2 pole filter reduces aliased power, so output noise voltage exceeds perfect dual slope integrator by only 1%.



CONCLUSION: 10 MHz ADC is sufficient for 1MHz pixel rate.

Digital CDS requires no parameter changes to work at lower pixel rates, other than number of samples to average. Main alias moves to slightly higher frequency as passband moves to lower frequency.