

LAr Slice Testboard Noise Investigation

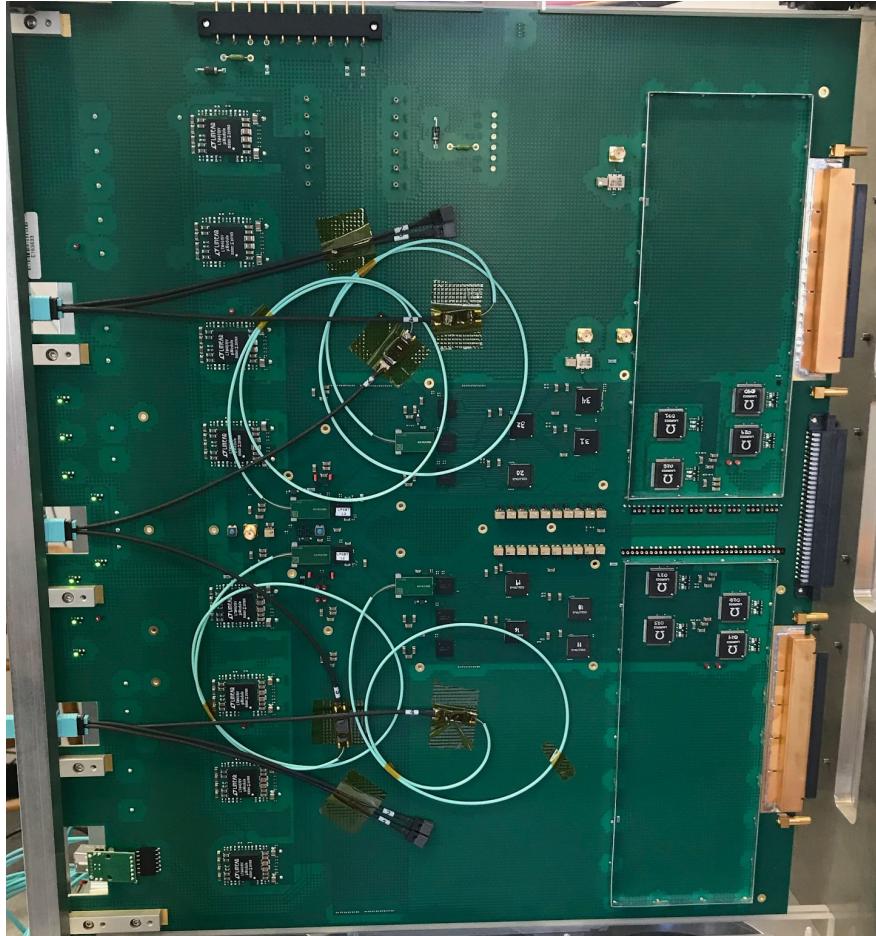
2021-04-13

Slice Testboard Noise Issues

- Pedestal noise measurements with Slice Testboard (that uses 8 LAUROC2 chips connected to 8 COLUTAv3 ADC chips) show some issues:
 - Individual channels seem significantly noisier than expected (particularly apparent for LO gain)
 - Coherent noise across channels is significantly higher than <5% specification and what was achieved previously with Analog Testboard (using LAUROC1 and COLUTAv2)
- As summarized in these slides, we have been systematically investigating these issues, trying many different configurations and making many different measurements to try shed light on what is going on
- Two main noise features observed: 250kHz line and 20kHz “bump”
 - 20kHz noise appears to be main source of correlated noise

Slice Testboard Setup, LAUROC Configuration

Slice Testboard in Test Setup



- v1.1 slice testboard in test setup
- 8 LAUROC2 + 8 COLUTAv3 chips
- Readout via IpGBTs into FELIX
- Inject signals through dedicated SMA input into LAUROC20 ch4 input
- Configuring LAUROCs with defaults in LAUROC2 datasheet
 - Using 25Ohm, 10mA settings
 - sw_R025_10mA = 1
 - sw_R025_5mA = 0

Reminder: DRE and MDAC Inputs on COLUTAv3

COLUTA ch1 DRE



COLUTA ch2 DRE



COLUTA ch3 DRE



COLUTA ch4 DRE



COLUTA ch5 MDAC



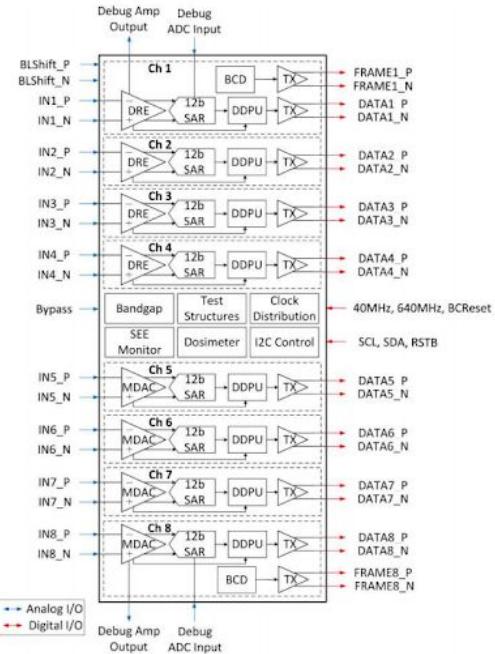
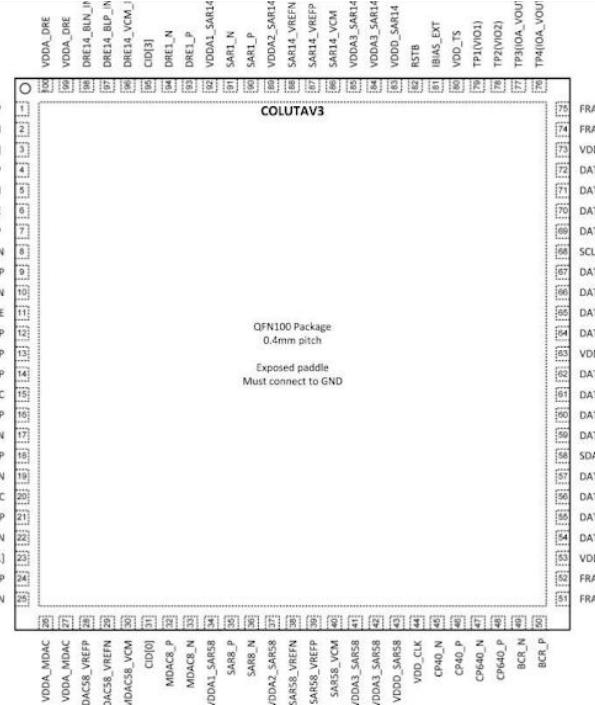
COLUTA ch6 MDAC



COLUTA ch7 MDAC



COLUTA ch8 MDAC

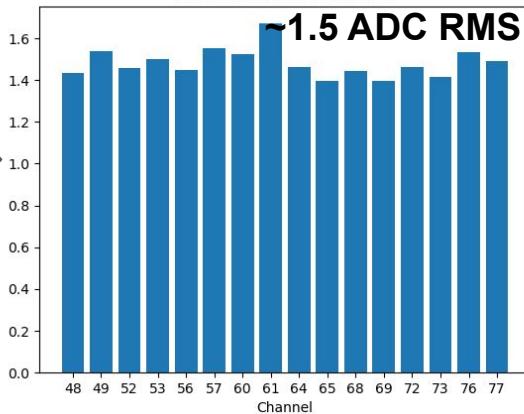


- COLUTAv3 has two different input types, ch1-4=DRE, ch5-8=MDAC
- For these studies, **DRE configured to use fixed 1x gain mode**, MDAC is effectively 4x gain
 - Impacts measured noise magnitudes, but channel performance is similar
- Each LAUROC outputs to 4 DRE channels, 4 MDAC
 - LAUROC ch1 LG+HG = DRE, ch2 HG+LG = DRE, ch3 LG+HG = MDAC, ch4 HG+LG = MDAC

Standard Slice Testboard Noise Measurements

LOW GAIN

RMS DRE Lo Gain Run0434

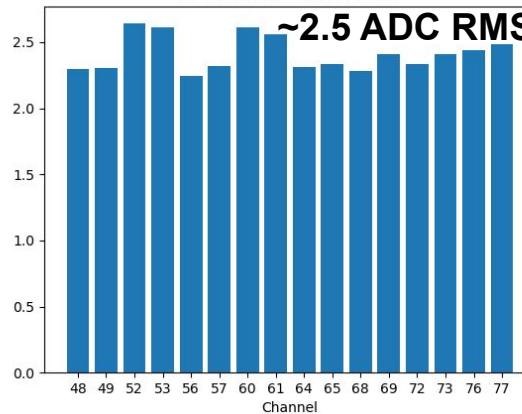


DRE Chs
(fixed 1X gain, to
avoid issues of
DRE with shifted
baseline)



HIGH GAIN

RMS DRE Hi Gain Run0434



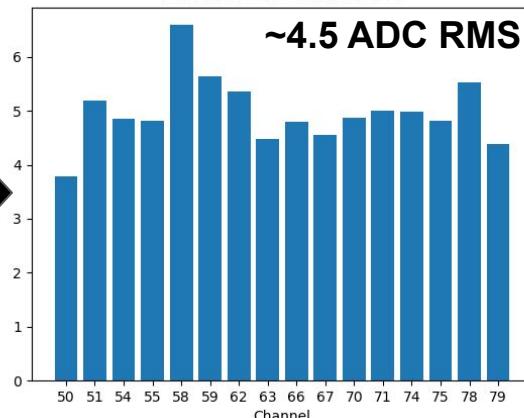
Noise measurements made
with no detector load on
LAUROC inputs

Expect ~4x more noise on
MDAC chs vs DRE chs in 1X
gain mode, by design

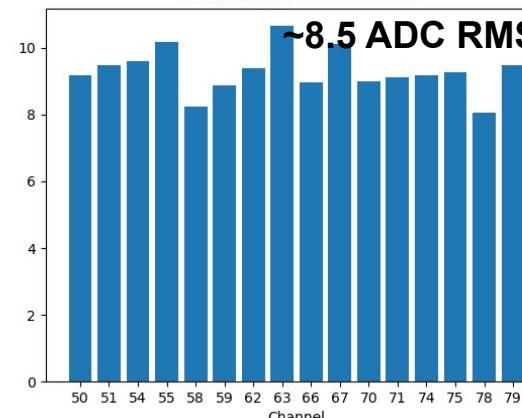
MDAC Chs



RMS MDAC Lo Gain Run0434



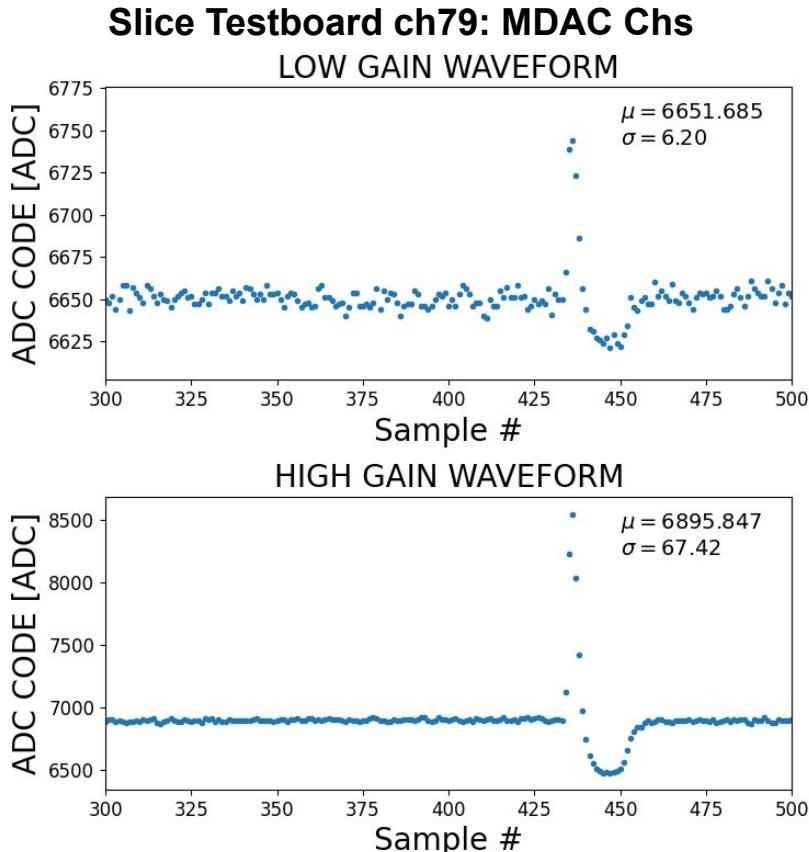
RMS MDAC Hi Gain Run0434



Sampling performance for
MDAC and DRE channels
similar in CV3 testboard
measurements

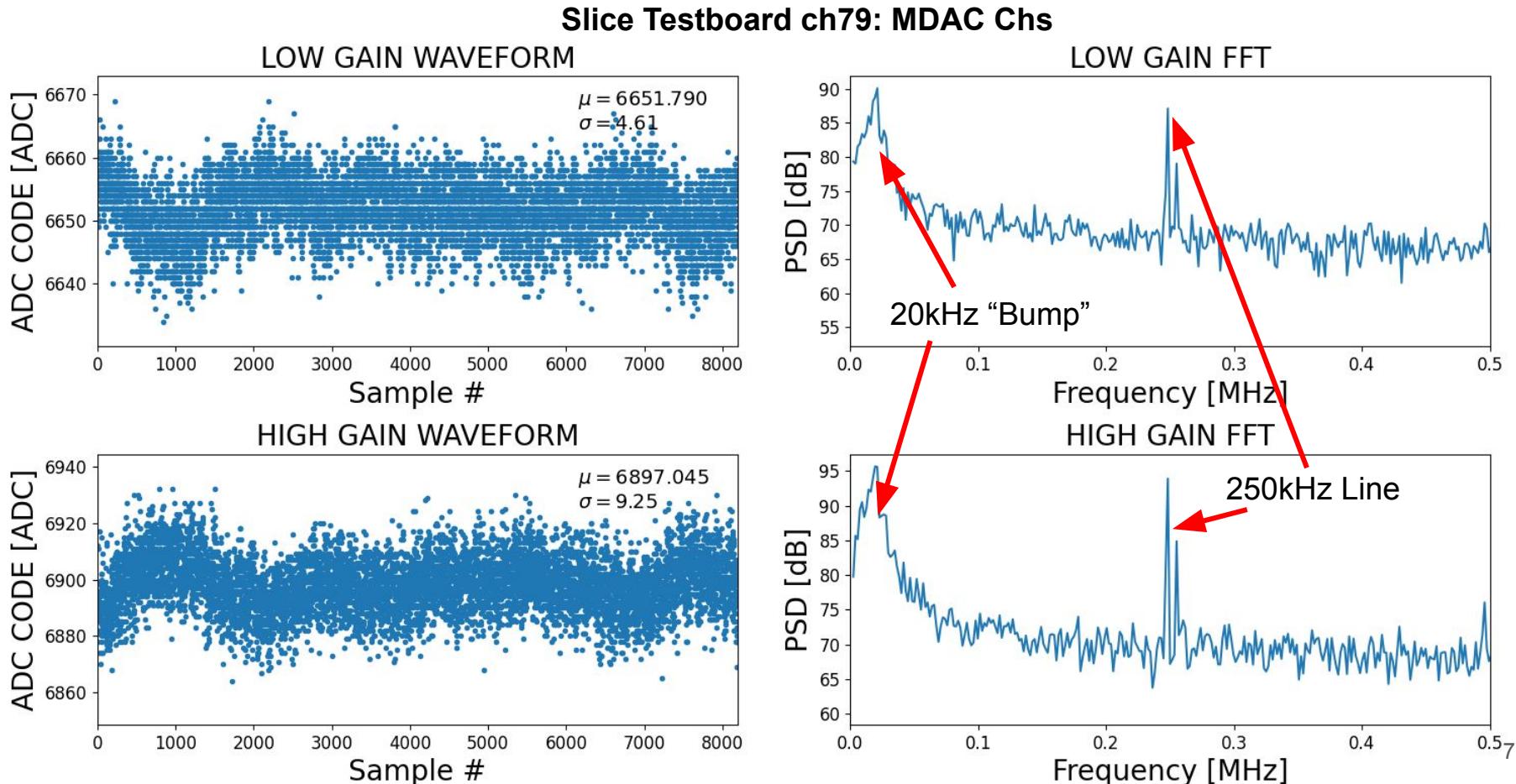
Notes: (1) HG channel noise
only ~2 times LG noise
(2) COLUTA-only noise
~1.3 ADC counts

Relative Gain Measured with Injected AWG Signal



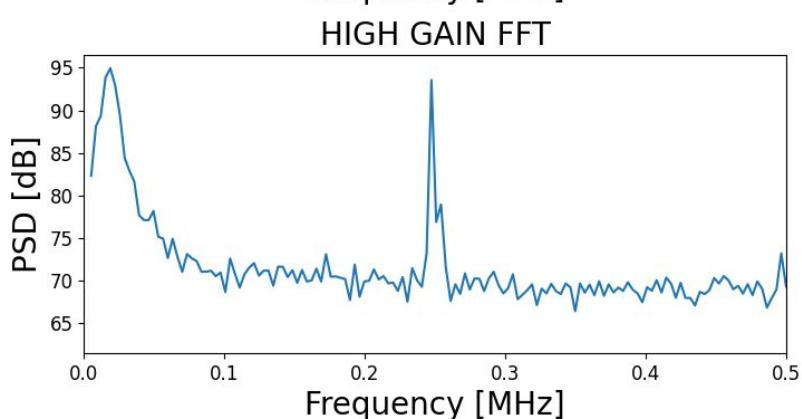
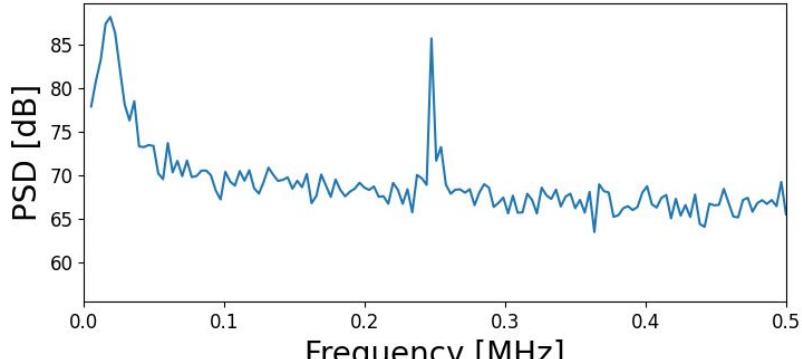
- Inject AWG signals through one of the LAUROC inputs
- Observe LAr-like signal on COLUTA, LAUROC+COLUTA signal path working on slice testboard!
- Rough estimate ~ 20 x relative gain on pulse signals between HG and LG channel
- Reminder: observed noise on HG channels generally only 2x higher than LG channels
 - LG channels noisier than expected? (would expect to be dominated by COLUTA noise and quantization error of ~ 1.3 ADC counts?)
 - As will be shown, results show also “excess noise” in HG channels, but less apparent due to overall higher noise level)

Main Noise Features: 20kHz Bump+250kHz Line in FFT

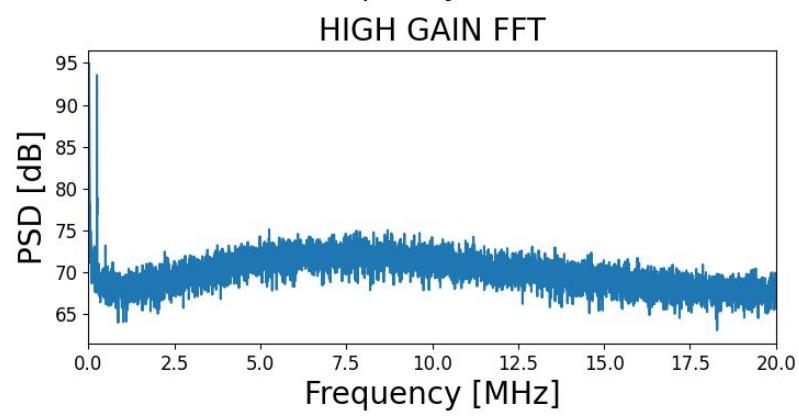
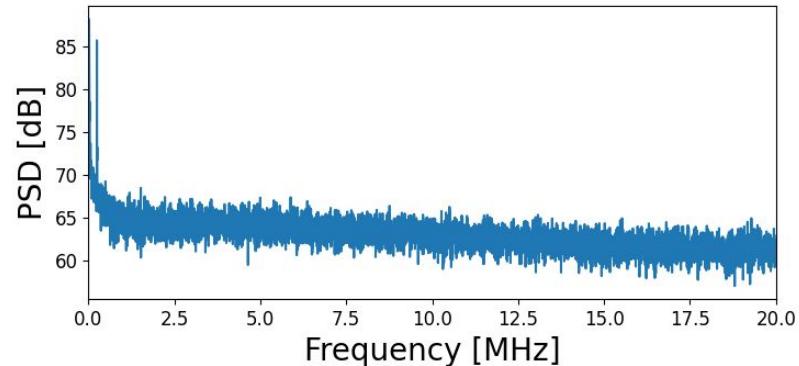


20kHz and 250kHz Noise Features are Dominant

Slice Testboard ch79 FFTs 500kHz Range
LOW GAIN FFT



Slice Testboard ch79 FFTs 20MHz Range
LOW GAIN FFT



Noise is >10-20% Correlated Across Slice Testboard Halves

LOW GAIN Chs

Run 0434 MDAC + DRE Pairwise Noise Correlation [%], lo gain

channel048	100	10	11	11	9	8	11	8	8	10	10	11	6	4	8	10	-2	-2	-1	-1	1	0	2	0	-1	-1	-1	2	2	3	4	0	0
channel049	10	100	6	9	9	8	4	8	9	7	6	10	5	5	5	6	0	0	-2	-2	0	0	-1	-2	-5	-1	0	-3	-1	1	1	1	
channel050	11	6	100	13	11	6	11	7	8	9	11	9	6	7	8	12	-1	0	0	0	0	1	3	1	-1	-2	-1	3	0	1	0	1	
channel051	11	9	13	100	10	9	9	9	10	10	10	7	10	10	10	-1	0	-2	-1	-3	2	1	1	-3	0	-2	1	1	2	1	-1	-1	
channel052	9	9	11	11	100	16	14	13	8	7	11	8	12	11	13	14	-1	0	4	0	0	-3	-2	0	0	2	-3	-2	-2	-5	-4	-3	-1
channel053	8	8	6	10	16	100	14	15	9	8	8	12	12	15	17	0	0	0	-4	-2	-2	0	-4	-1	-3	-3	-6	-4	-2	-3	-3	-4	-5
channel054	11	4	11	9	14	14	100	11	6	12	11	14	15	14	16	2	2	0	3	-1	1	-1	0	1	0	4	-5	-3	-3	-3	-3	-3	
channel055	8	8	7	9	13	15	11	100	10	5	7	9	14	13	15	17	1	-1	0	-1	-3	-4	0	0	-2	-2	-5	-2	-7	-6	-4	-7	
channel056	8	9	8	9	8	9	10	100	14	12	14	7	9	8	8	-2	-3	0	-2	-3	1	1	0	-1	1	-1	1	0	1	0	1		
channel057	10	7	9	10	7	8	6	5	14	100	10	13	6	4	6	5	-2	-3	-1	0	-1	0	1	-3	0	0	0	2	0	-1	-1		
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channel060	6	5	6	7	12	12	14	14	7	6	7	8	100	16	21	20	3	2	6	4	2	0	-1	2	-1	1	-1	0	-5	-6	-9	-6	
channel061	4	5	7	10	11	12	15	13	9	4	8	9	16	100	21	19	3	3	4	1	-1	0	2	-1	-2	-2	-1	1	-5	-4	-7	-5	
channel062	8	5	8	10	13	15	14	15	8	6	9	9	21	21	100	25	3	5	5	4	0	0	1	-1	-1	1	-3	0	-10	-7	-7	-8	
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channel065	-2	0	0	0	0	0	2	-1	-3	-3	-2	-2	2	3	5	3	13	100	14	13	8	8	6	10	7	5	8	8	5	4	6	6	
channel066	-1	-2	0	-2	4	0	0	0	0	-1	-2	-1	6	4	5	5	15	14	100	12	10	9	9	8	8	10	9	7	7	6	8		
channel067	-1	-2	0	-1	0	3	-1	2	-2	-3	-1	4	1	4	2	14	13	12	100	9	10	8	10	7	10	4	6	5	6	8			
channel068	-1	0	0	-3	0	-4	-1	-3	-3	-1	-2	2	2	-1	0	-1	13	8	10	9	100	9	13	10	10	7	11	8	9	8	9	12	
channel069	0	0	1	2	0	-2	1	-4	1	0	-1	2	0	0	0	9	8	9	10	9	100	11	11	9	8	10	9	11	9	9	11		
channel070	-2	-1	3	1	-3	-2	1	0	1	1	1	0	-1	2	1	0	10	6	9	8	13	11	100	14	7	9	9	7	10	10	10	10	
channel071	0	-2	-1	2	-2	0	1	0	3	-3	2	-1	-2	13	10	8	10	10	11	14	100	12	6	9	8	10	10	10	10	10	10		
channel072	-1	-5	-2	-3	-2	-4	0	-2	1	-1	-2	-1	-3	11	7	8	8	10	9	9	12	100	12	11	12	8	6	9	9	9	9		
channel073	-1	-1	-1	0	-1	-1	-2	1	0	1	2	1	-2	1	1	8	5	10	7	7	6	12	100	10	8	7	8	8	11				
channel074	-1	0	3	-2	0	-3	0	-5	-1	0	0	2	-1	-1	-3	-3	10	8	9	10	11	10	9	100	8	10	8	9	12				
channel075	-2	-3	0	1	2	-3	4	-2	1	0	0	2	0	1	0	-1	10	8	9	4	8	9	9	12	8	10	8	9	8	9	10		
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channel077	-3	1	0	2	-2	-4	-3	-6	1	0	-2	2	-6	-4	-7	-5	8	4	7	5	8	9	10	6	8	8	8	14	100	16	15		
channel078	-4	1	1	1	-2	-2	-3	-4	0	-1	2	3	-9	-7	-7	-5	7	6	6	6	9	9	10	9	8	9	9	18	16	100	18		
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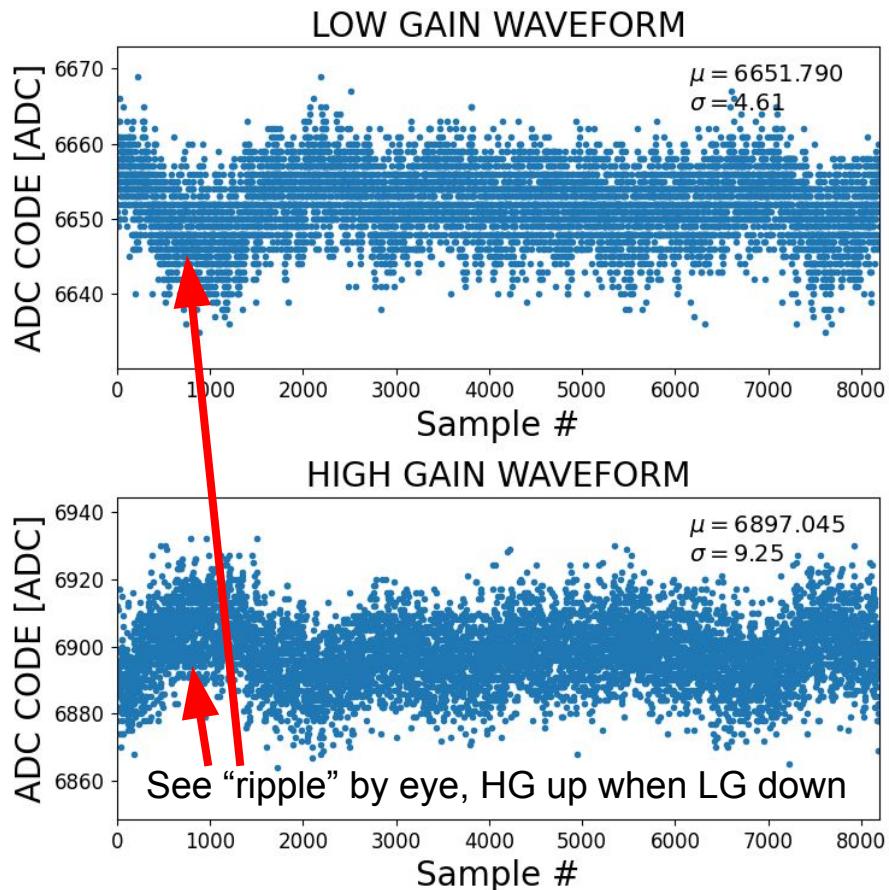
channel048
channel049
channel050
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channel068
channel069
channel070
channel071
channel072
channel073
channel074
channel075
channel076
channel077
channel078
channel079

HIGH GAIN Chs

Run 0434 MDAC + DRE Pairwise Noise Correlation [%], hi gain

channel048	-100	13	11	13	10	12	9	12	12	14	12	12	8	7	-1	-2	-1	-2	-1	-1	0	0	-1	1	0	1	3	1	2						
channel049	-13	100	14	10	11	10	12	13	11	10	7	10	9	9	0	0	0	-1	-1	2	1	-1	-2	1	4	1	3	2	-1	2					
channel050	-11	10	100	13	8	8	8	9	10	9	13	11	7	8	8	9	-1	-2	-2	-4	-2	0	-1	0	0	1	-1	1	0	2	0				
channel051	-13	14	13	100	12	13	11	12	12	11	15	13	8	9	12	10	-3	-2	-5	-4	-3	-2	-4	1	-2	0	-1	1	0	0	0	0			
channel052	-10	10	8	12	100	15	14	17	9	7	18	17	16	2	3	1	2	-3	-1	0	-3	-2	-1	1	-2	0	-1	-7	-7	-9	-6				
channel053	-12	11	8	13	15	100	12	13	10	7	10	8	15	17	18	15	2	1	2	0	0	-1	-3	-2	-1	-3	-4	-5	-6	-7	-8				
channel054	-9	10	8	11	15	12	100	11	9	11	8	16	14	15	16	3	2	3	1	-1	-1	2	-3	-2	0	-2	-1	-5	-5	-3	-3				
channel055	-12	12	9	12	14	13	11	100	9	8	10	7	17	17	18	18	1	3	2	2	-4	1	-2	-1	-4	-1	-2	-1	-3	-6	-3	-7			
channel056	-12	13	10	12	7	10	9	9	100	14	16	16	7	8	7	10	-1	-3	-2	-3	-0	1	1	0	1	1	2	1	2	1	2				
channel057	-14	11	9	11	9	7	11	8	14	100	16	16	8	6	7	9	-1	-3	-2	-1	-2	1	-1	-2	0	-1	1	1	2	1	1	1			
channel058	-12	11	13	15	9	10	8	10	16	16	100	15	8	9	10	9	-2	-3	-3	-4	-2	1	-1	-3	-1	0	1	4	1	0	1				
channel059	-12	10	11	13	10	8	7	6	100	4	7	9	9	3	5	4	6	5	4	5	4	5	4	6	5	0	-1	-2	-1	-2	-1				
channel060	-8	7	7	8	18	15	16	17	7	8	8	4	100	25	25	26	5	5	5	6	-1	-1	2	-3	-4	-3	-10	-11	-10	-10					
channel061	-7	10	8	9	17	17	14	17	8	6	9	7	26	100	26	24	6	7	7	1	1	0	2	-4	-1	-3	-1	-10	-10	-10	-10				
channel062	-8	9	8	12	16	18	15	18	7	7	10	9	25	26	100	26	4	5	5	6	0	-1	-2	1	-3	-1	-2	-9	-10	-12	-10				
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channel065	-2	0	-2	-2	3	1	2	3	-1	-3	2	3	1	2	3	1	-1	-2	-3	-3	5	7	5	4	17	100	17	17	17	12	9	12	10	6	8
channel066	-1	0	-2	-5	1	2	3	2	-2	-2	-3	1	5	7	5	6	17	17	10	16	10	10	13	12	13	11	11	8	9	6	9	9			
channel067	-2	-1	-4	-4	2	0	1	2	-3	-1	-4	-3	6	7	6	7	19	17	16	10	10	11	11	8	13	9	7	8	8	9	11	11	11		
channel068	-1	-1	-2	-3	0	-																													

20kHz Noise Visible as ~50us “Ripple” in Waveforms, Anti-Correlated Between LG and HG Channels



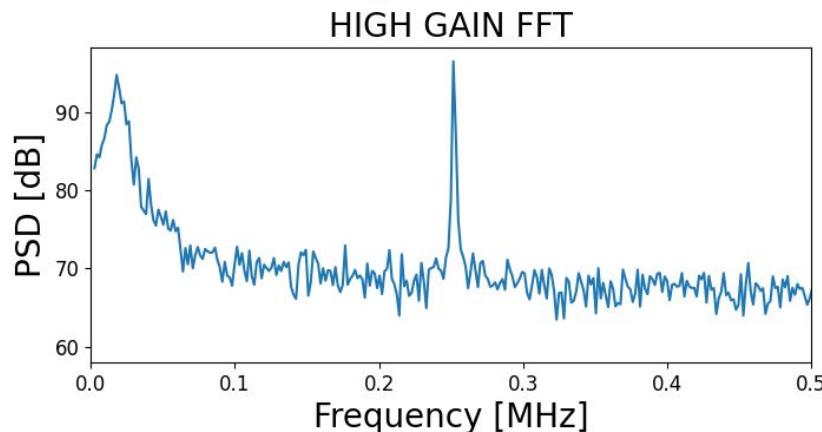
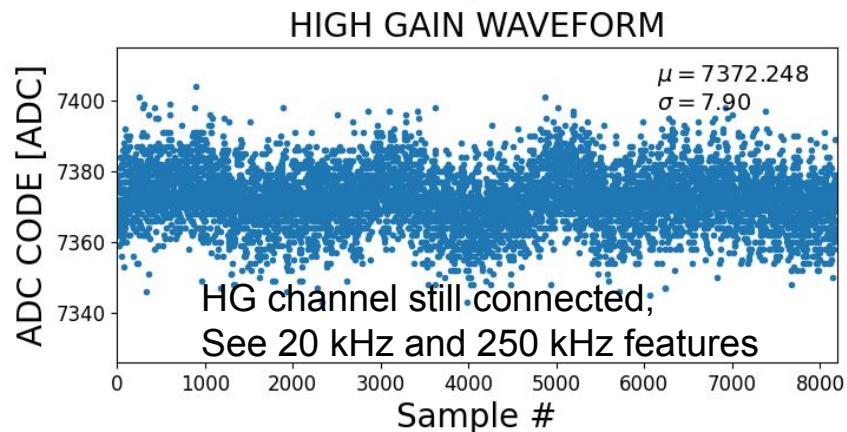
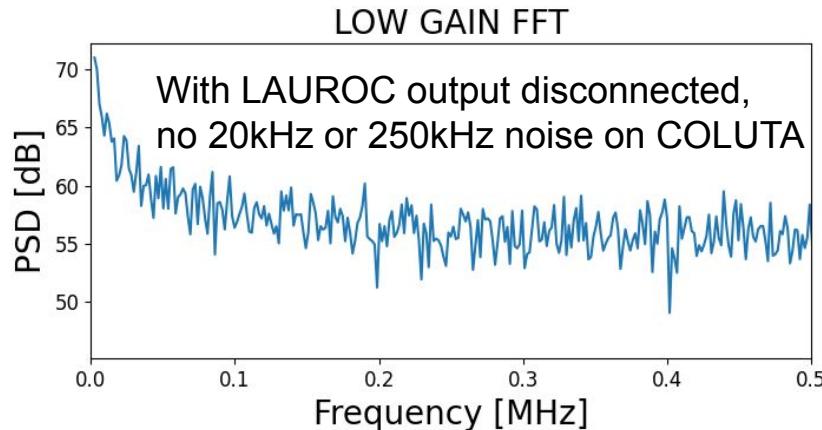
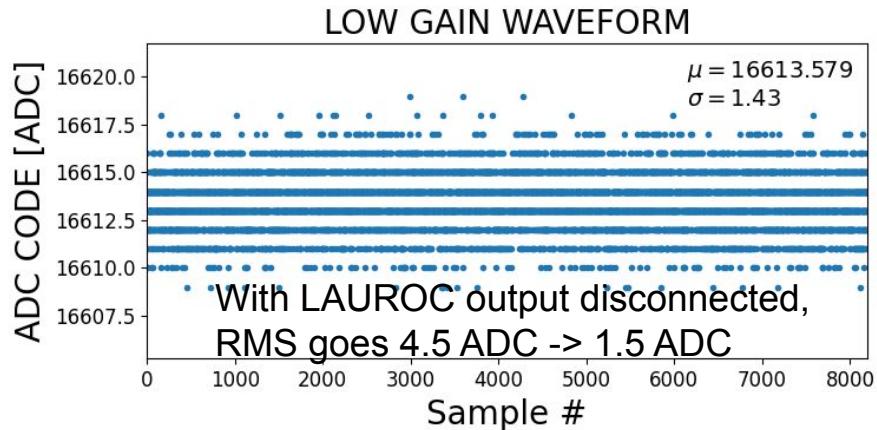
Correlation Plot, All Chs on Upper Board Half

Run 0434 MDAC + DRE Pairwise Noise Correlation [%], HiLo gain

channel064hi	-10	-12	17	15	17	15	19	15	12	10	-9	12	-10	12	-13	9	-10	12	-10	10	-11	14	-7	8	-7	9	-9	9	-10				
channel064lo	-12	10	-14	13	16	15	14	14	-12	13	-10	9	-14	10	-11	13	-11	11	-8	11	-10	-7	-9	8	-8	7	9	-7	9	-10			
channel065hi	-17	-14	10	-9	17	-16	17	17	12	10	9	-8	12	9	10	-12	12	-9	11	-9	10	-12	-8	10	-9	6	-8	8	-8	8	-10		
channel065lo	15	13	-9	10	13	14	-13	13	-8	8	-5	8	-7	6	-7	10	-7	7	-10	5	-9	8	-9	8	-5	5	-7	4	-8	6	-6	6	
channel066hi	17	-16	17	13	10	-12	16	-16	10	11	10	-8	13	-10	12	-10	13	-10	11	-8	11	-11	11	-9	8	-9	9	-7	6	-8	9	-8	
channel066lo	-15	15	16	14	12	10	7	17	12	11	10	10	9	-11	9	-9	8	-8	10	-10	9	-12	9	-7	7	-6	6	-8	8	-8	8	-10	
channel067hi	19	-14	17	13	16	17	10	12	10	9	-6	11	-11	10	-11	11	-7	11	-8	8	-11	13	-8	8	-8	9	-7	7	-9	8	-8		
channel067lo	15	14	17	13	16	12	10	6	9	-7	8	-10	12	7	9	-8	7	-9	10	-10	4	-8	6	-7	5	-7	6	-8	6	-8	8	-10	
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channel068lo	-12	13	-10	8	-11	10	-9	9	-10	10	12	9	-13	13	-10	10	-9	10	-9	7	-8	11	8	-7	9	-9	8	-10	9	-6	12	-12	
channel069hi	-10	-10	9	-5	10	-10	10	-7	12	12	10	-5	-14	-11	15	10	10	-10	12	-7	10	-8	9	-11	11	-10	9	-8	8	11	9	-6	
channel069lo	-9	9	-8	8	-8	9	-6	10	-11	9	-5	10	15	11	11	-11	10	9	-10	8	-8	10	-11	9	-10	11	9	-9	9	-11	11	-10	
channel070hi	-12	-14	12	-7	13	-11	11	-8	16	13	14	15	10	-11	17	-12	12	-9	14	-10	12	-13	8	-10	-9	13	-10	11	12	13	-11		
channel070lo	-10	10	-9	6	10	9	11	8	15	13	11	11	11	11	11	11	11	11	12	7	11	9	10	-7	9	-10	9	-10	10	10	-10		
channel071hi	-12	-11	10	-7	12	-9	10	-12	13	10	15	11	17	14	10	-9	8	-10	12	-9	12	-9	10	-8	10	-9	13	-10	10	-10			
channel071lo	-13	13	-12	10	-10	8	-11	10	15	10	-10	11	-12	14	-9	10	-10	12	-10	6	-8	9	-11	8	-9	10	-12	10	-9	10	-10		
channel072hi	9	-11	12	-7	13	-9	11	-9	14	-9	10	-12	11	-8	10	-10	12	-11	8	-14	13	11	-11	13	-11	12	-9	10	12	10	-11		
channel072lo	-10	11	-9	7	10	8	-7	8	-11	10	10	9	-9	9	-10	12	-5	10	-9	12	-10	11	11	12	-11	8	-10	6	-10	9	-9	9	-9
channel073hi	-12	-9	11	10	11	10	11	-9	14	-9	12	10	14	-12	12	-10	9	10	-5	12	-10	11	11	10	12	-12	11	12	13	12	-11		
channel073lo	-10	8	-9	5	-8	10	-8	7	-7	7	-8	10	7	9	-6	8	-12	-5	10	-10	10	-8	7	8	-9	10	-11	10	-12	10	-12		
channel074hi	-10	11	9	-9	11	-10	8	-9	10	-8	10	-8	12	-11	12	-8	14	-10	12	-10	10	-6	13	12	12	-11	11	-10	11	12	-10	12	
channel074lo	-11	10	-10	8	-11	9	-11	10	-11	11	-8	10	-9	9	-9	13	-11	-10	10	-6	10	-12	8	-12	10	-12	8	-10	9	-12	12	-12	
channel075hi	-14	-10	12	-9	11	-12	13	-11	11	9	-11	13	-11	10	11	11	-11	11	9	13	-12	12	-7	13	-14	13	-12	11	12	13	-11		
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channel076lo	-7	7	-9	5	9	-7	8	-6	8	-9	10	-10	11	-9	7	-9	11	-8	12	-7	11	-10	8	-12	7	-11	12	-7	11	12	13	-17	
channel077hi	9	-9	6	-7	9	-6	9	-7	11	-9	9	-11	13	-9	10	-12	12	-7	11	-12	13	12	19	18	10	4	20	18	19	17			
channel077lo	-7	8	-8	4	-7	7	-7	5	-9	8	-8	9	-10	10	-8	-10	9	-6	11	8	-10	8	-12	8	-17	14	-14	15	15	15	15		
channel078hi	8	-8	8	-8	6	-6	7	-7	9	-10	8	-9	11	-9	10	-9	10	-10	12	-9	11	-10	11	-12	19	-18	20	15	10	13	20	17	
channel078lo	-9	7	-8	6	-8	6	-9	6	-8	9	-11	9	-12	10	-9	10	-12	9	-13	8	-12	9	-12	9	-20	18	16	13	10	18	18		
channel079hi	9	-9	8	-8	6	-8	6	-11	6	-9	13	-10	13	-9	10	-12	10	-12	9	-10	11	-12	10	-13	19	19	19	19	19	19	19		
channel079lo	-10	7	-10	6	-8	8	-8	10	-12	6	-11	11	-10	11	-9	11	-11	12	-12	11	-10	19	-15	15	-17	18	-14	10	10	13	20	17	

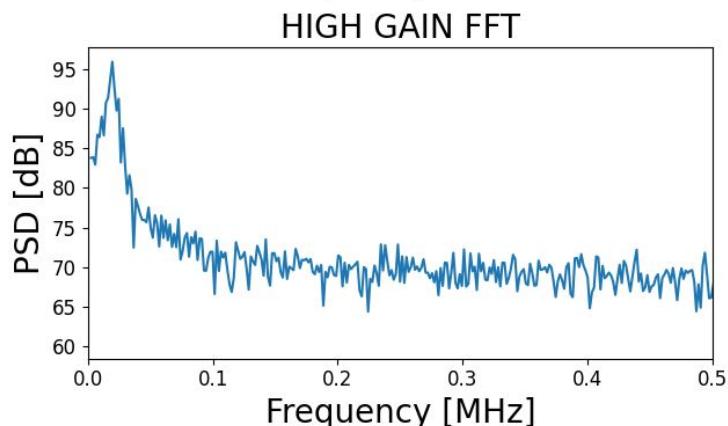
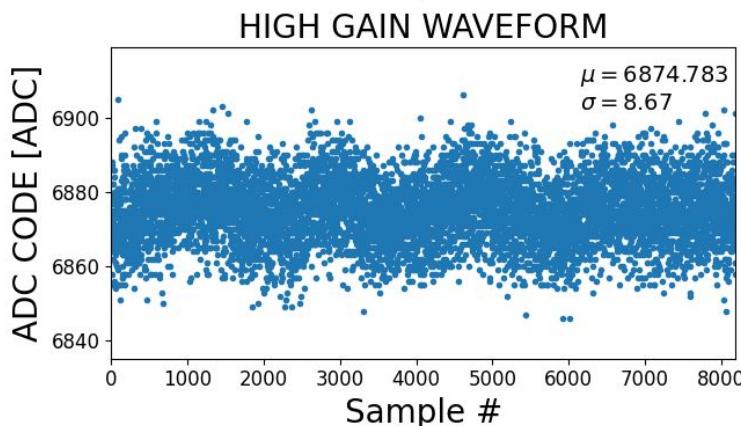
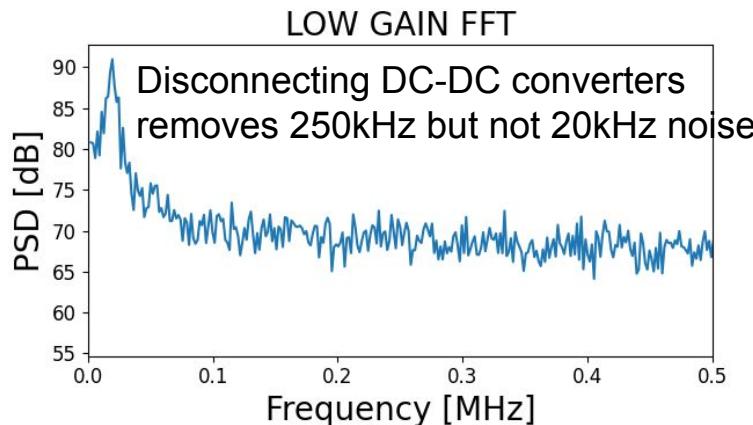
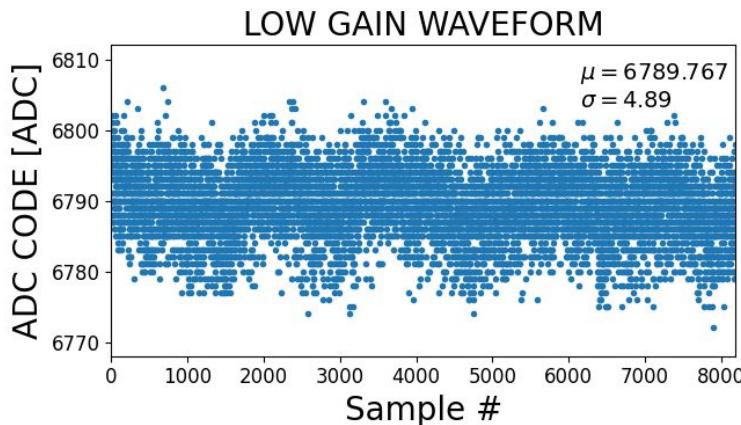
Noise Features Not Seen by COLUTA without LAUROC

Slice Testboard ch79: MDAC Chs
LG Ch Disconnected from LAUROC



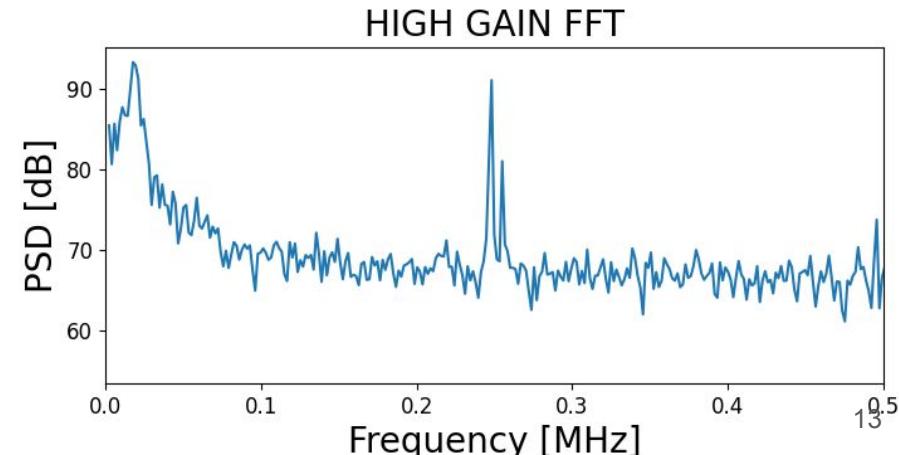
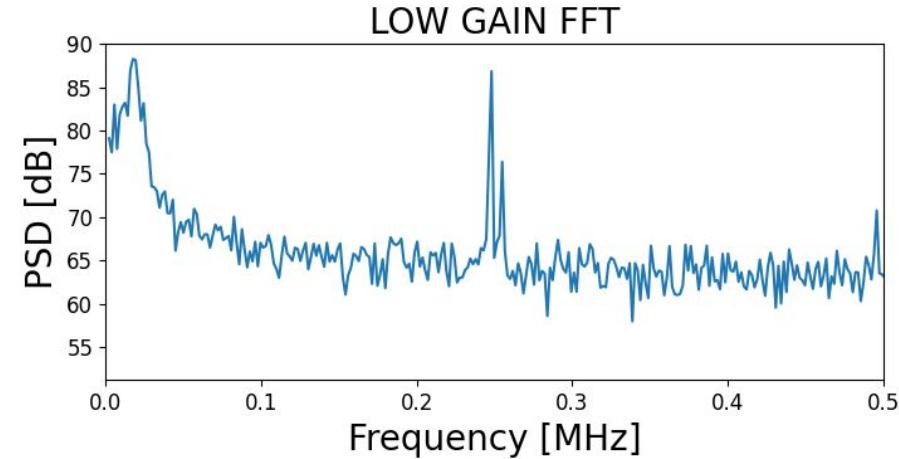
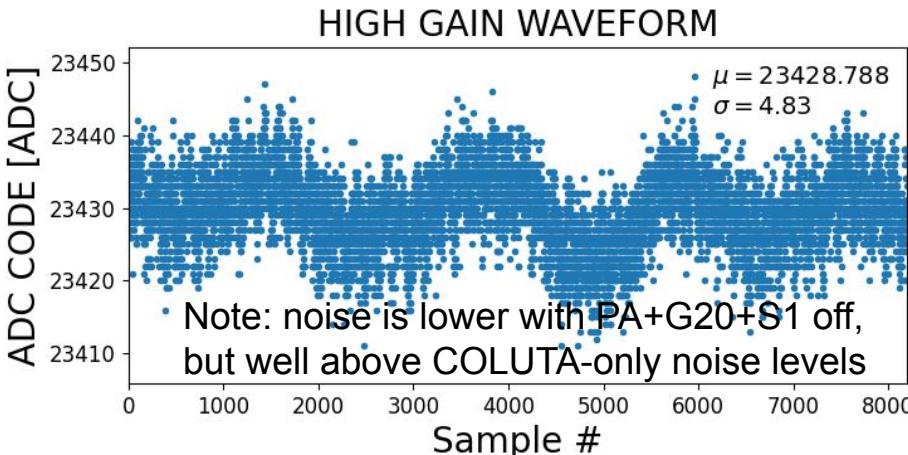
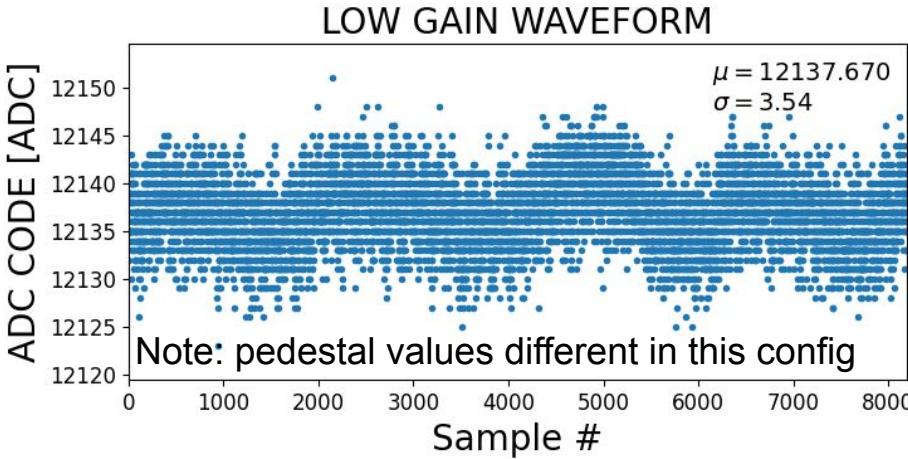
250kHz Noise Not Seen When Using External Linear PS (ie. DC-DC Converters Not Connected), but 20kHz Bump Remains

Slice Testboard ch79: MDAC Chs

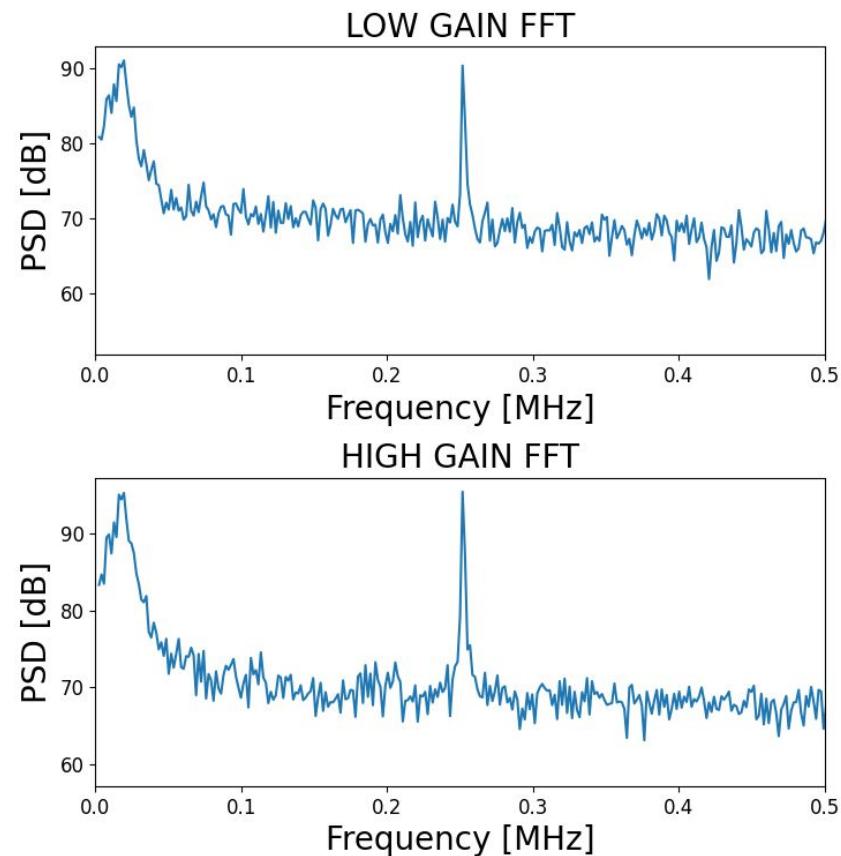
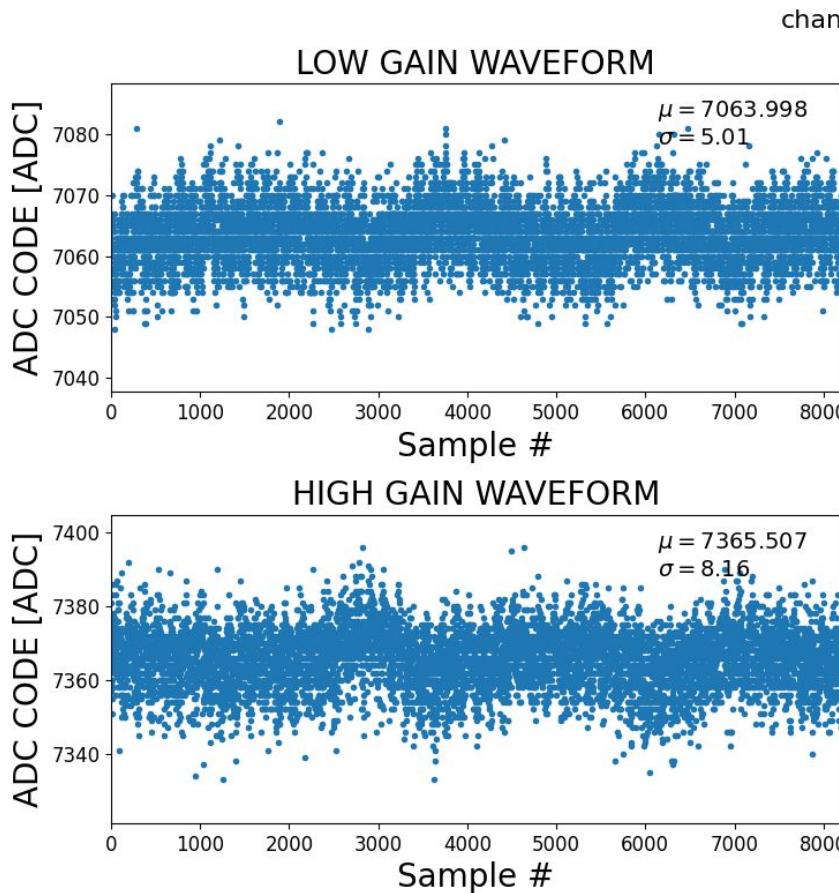


20kHz+250kHz Noise Remains with PA,G20,S1 Off

Slice Testboard ch79: MDAC Chs

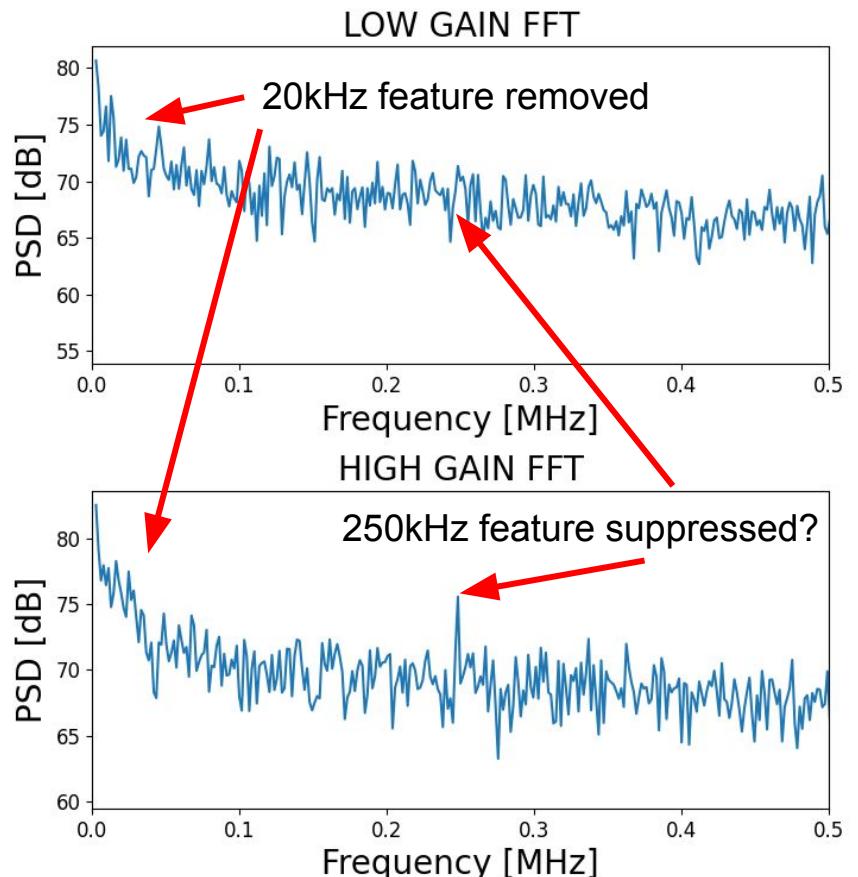
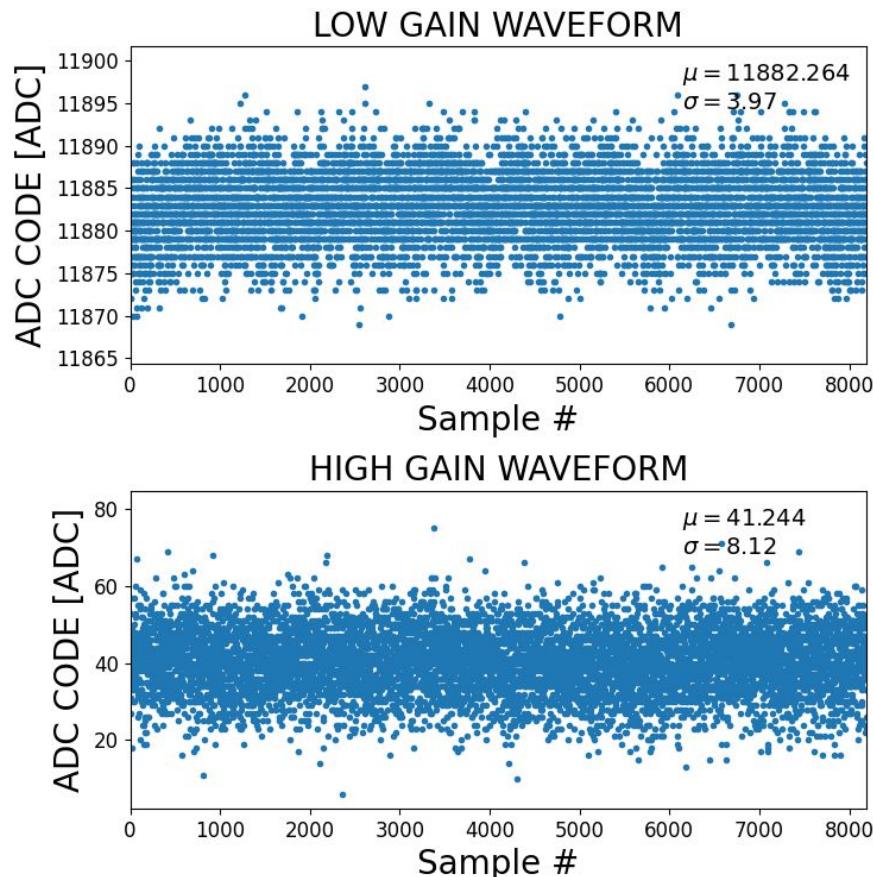


20kHz+250kHz Noise Remains with 50Ohm Resistors on LAUROC Outputs



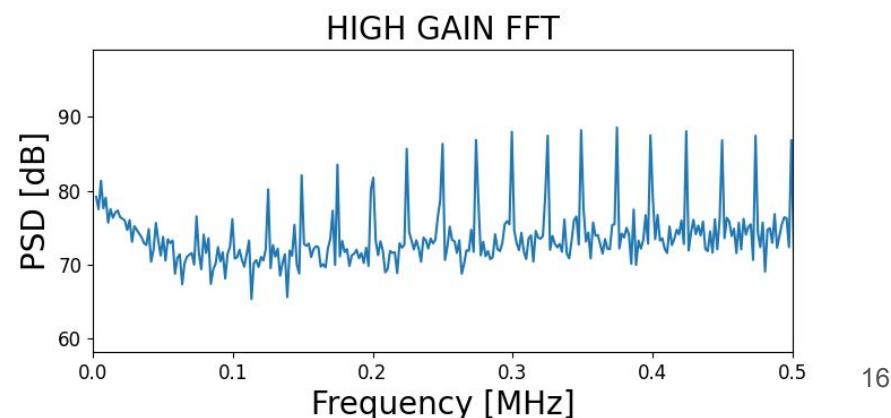
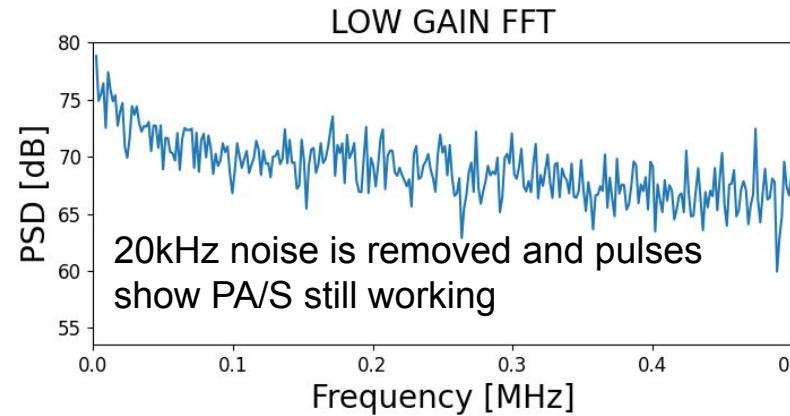
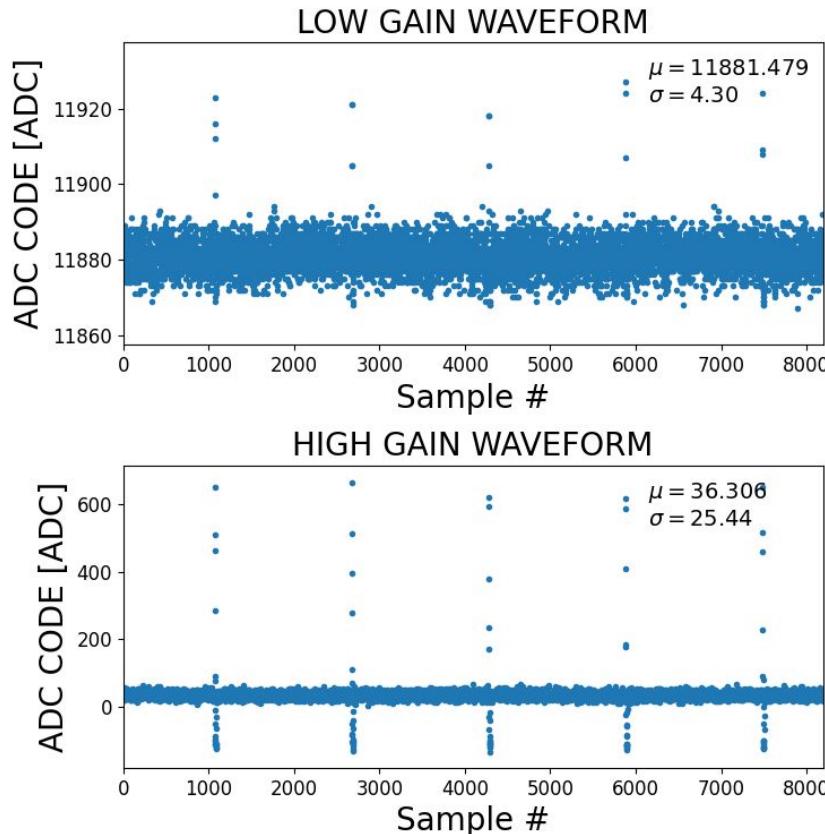
Setting DAC VDC LG/HG to Low Value Removes 20kHz Noise

Slice Testboard ch79: MDAC Chs
DAC VDC LG = 0, DAC VDC HG = 5

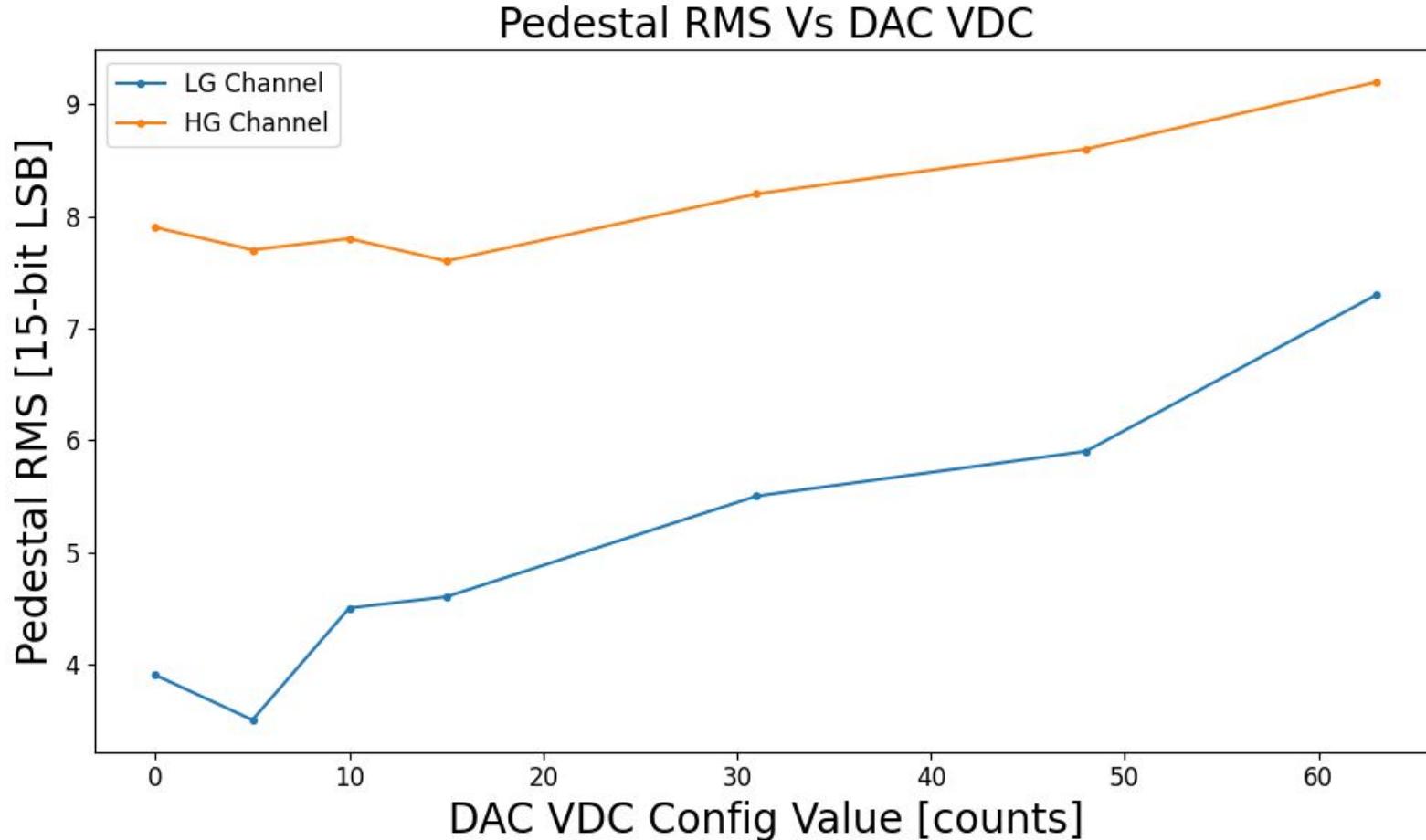


Pulse Signals Still Visible with Low DAC VDC (so PA/S still working)

Slice Testboard ch79: MDAC Chs
DAC VDC LG = 5, DAC VDC HG = 5

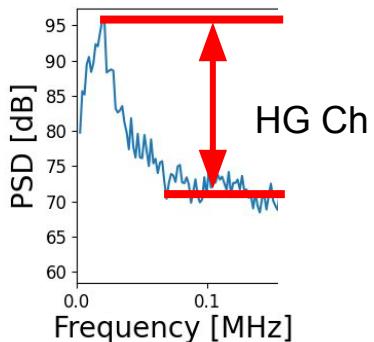
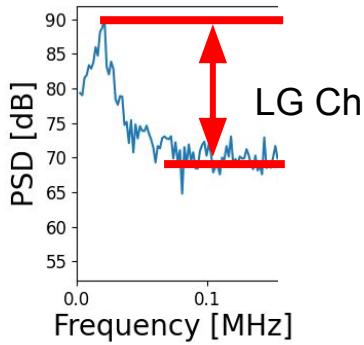


Measured Pedestal RMS Vs DAC VDC

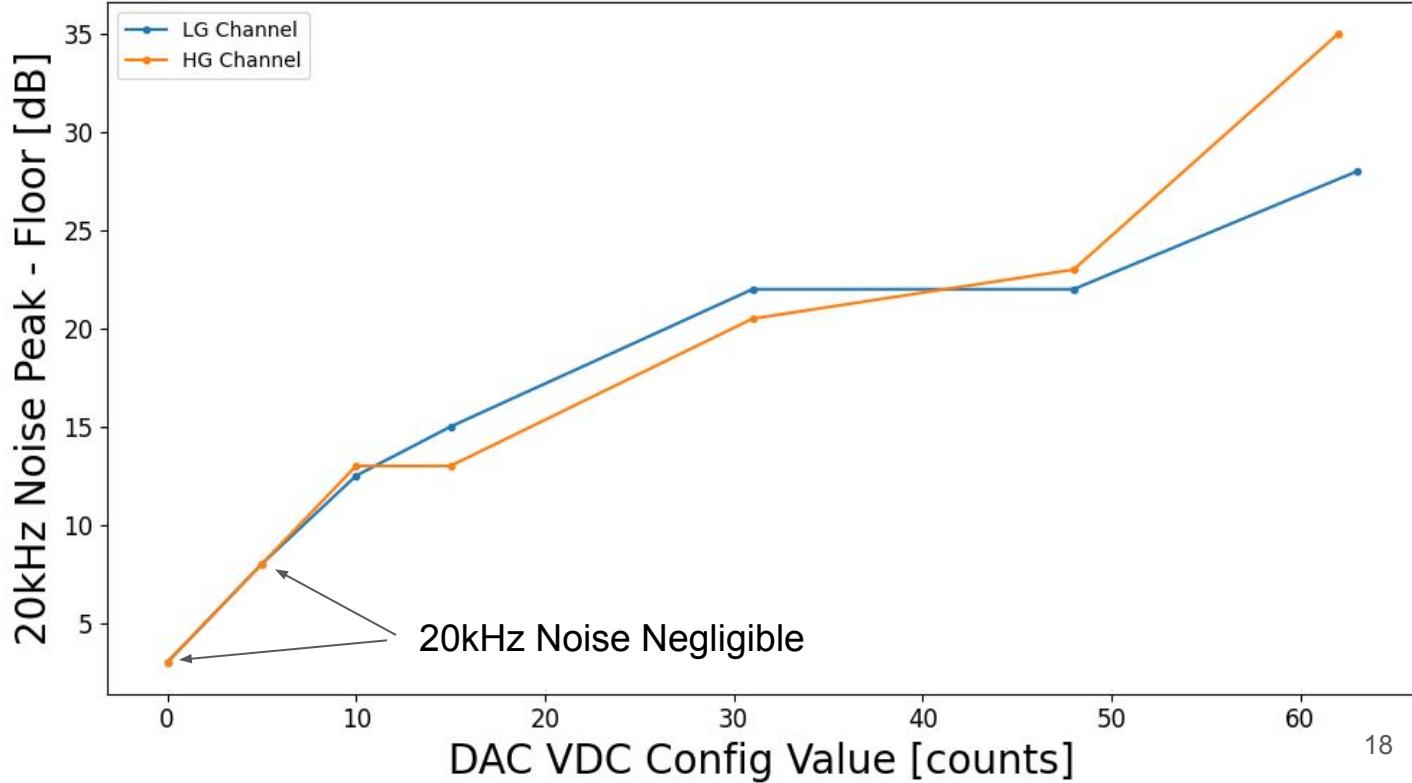


Measured 20kHz Noise Magnitude Vs DAC VDC

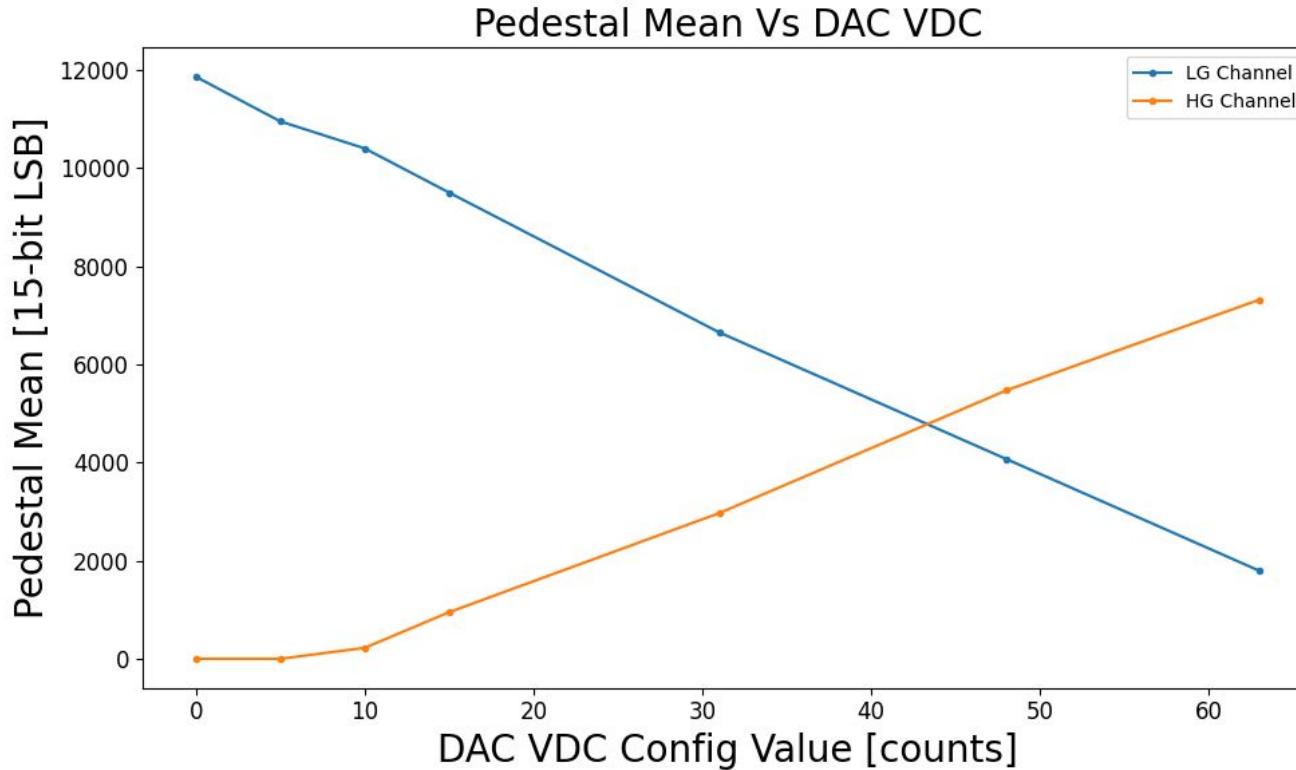
Measurement of 20kHz Peak Size
wrt Noise Floor



20kHz Noise Peak Size wrt Noise Floor



Pedestal Mean Vs DAC VDC



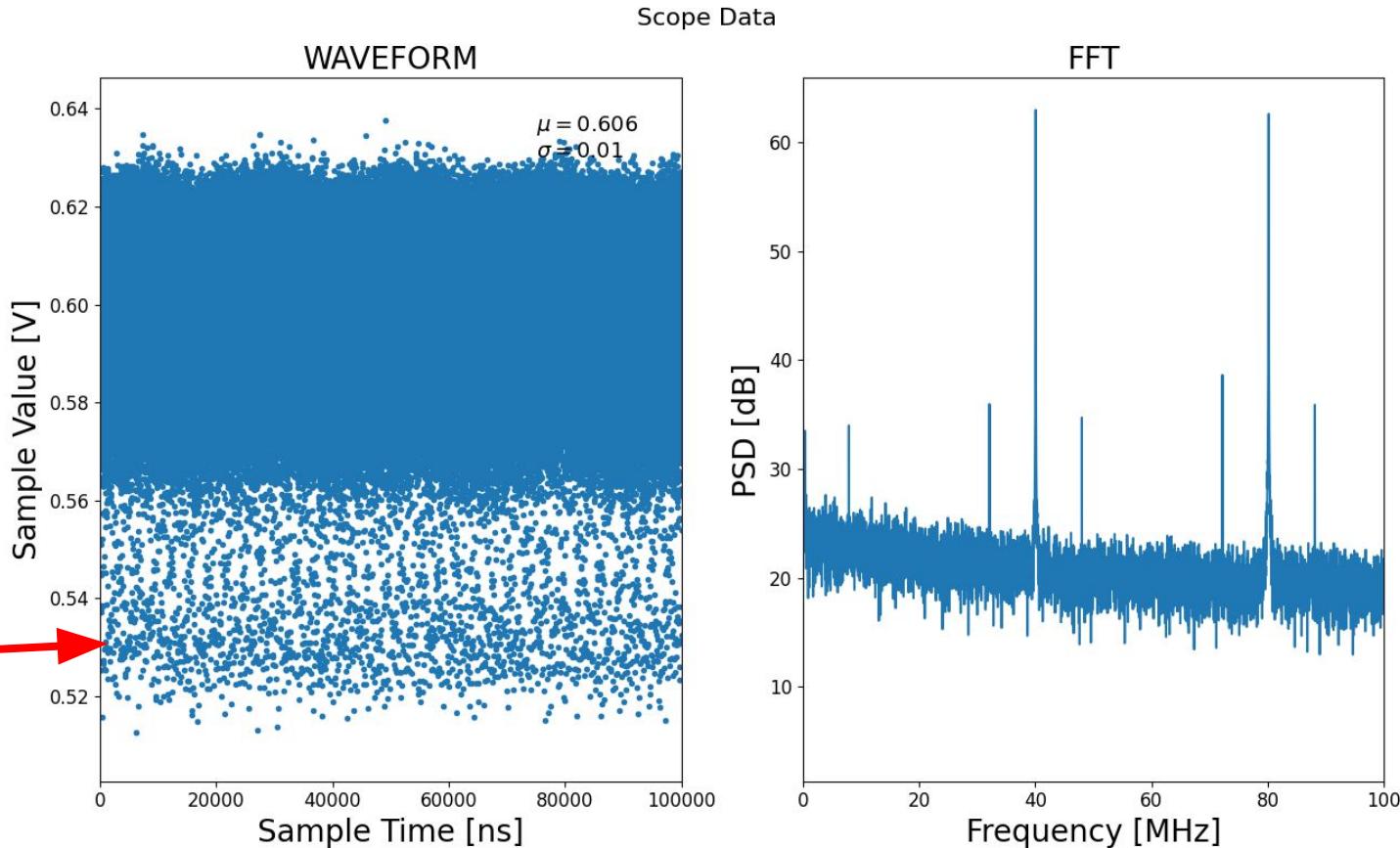
- Low gain and high gain channels vary differently wrt DAC VDC value
- Related to anti-correlated low gain and high gain 20kHz noise?

Correlated Noise <5% with Low DAC VDC

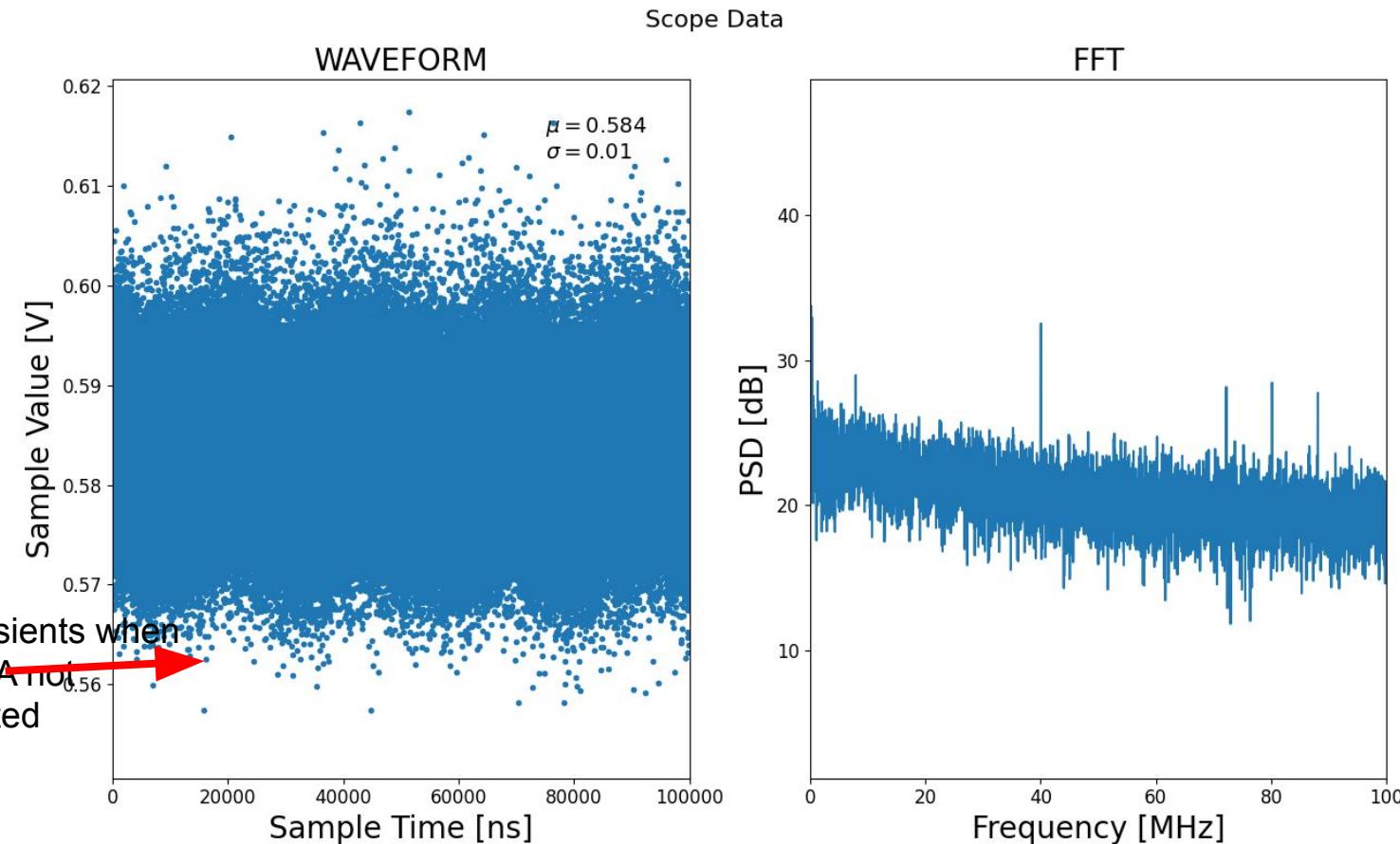
	Run 0429 MDAC + DRE Pairwise Noise Correlation [%], lo gain																															
	channel048	channel049	channel050	channel051	channel052	channel053	channel054	channel055	channel056	channel057	channel058	channel059	channel060	channel061	channel062	channel063	channel064	channel065	channel066	channel067	channel068	channel069	channel070	channel071	channel072	channel073	channel074	channel075	channel076	channel077	channel078	channel079
channel048	0 3 1 2 2 1 0 -2 2 -1 1 2 0 3 3 -2 0 1 0 0 0 2 1 0 0 1 0 -1 1 2 0 -2	3 0 1 2 0 1 -2 2 1 2 4 -2 0 1 2 0 2 2 0 0 0 1 -1 0 1 1 -1 1 0 -2 0 -1	-1 1 0 3 1 1 0 0 0 1 0 -1 1 1 0 3 -1 1 1 0 0 2 0 -2 2 0 -2 0 2 3 1 1	-2 2 -3 0 1 -1 0 -1 -1 1 0 1 -1 1 -4 1 -1 2 2 1 0 0 1 2 -2 2 -2 1 0 -1 2	-2 0 -1 1 0 2 2 1 1 -1 2 1 2 0 3 -1 2 0 0 3 0 0 2 1 -2 1 2 1 0 1 -1 1	-1 1 1 -1 2 0 0 0 1 1 0 1 2 2 2 1 -1 2 0 1 2 0 -2 2 -1 0 2 0 1 2 1 -1	-0 2 0 0 2 0 0 1 1 2 0 -4 1 4 2 2 2 -1 2 0 1 2 0 0 2 -3 2 2 -1 0 -1 1 -2	-2 2 0 -1 1 0 1 0 0 1 -1 -1 1 3 2 2 0 1 2 -3 0 -2 0 1 -2 2 2 1 -2 1 1 -2	-2 1 0 -1 1 1 1 0 0 4 2 0 0 1 0 -2 1 3 1 -2 1 2 1 1 -2 3 -1 3 2 0 -1 1	-1 2 -1 -1 1 2 -1 4 0 0 2 1 1 -1 2 1 2 -1 1 1 -1 0 -1 0 3 -1 2 1 -2 1 -3	-1 4 0 -1 2 0 0 -1 2 0 0 1 2 1 0 -1 1 1 2 1 2 -1 0 2 -2 2 -1 3 2 2 0 1 1	-2 2 -1 0 1 1 -4 -1 0 2 1 0 2 -2 3 -3 1 0 -2 2 1 0 1 1 -3 1 1 1 1 -1 2	0 0 1 1 2 2 1 1 0 -1 2 -2 0 2 6 5 3 -2 0 1 4 -1 3 -3 0 -2 2 5 0 0 0 2	-3 -1 1 -1 0 2 4 3 1 1 1 -2 2 0 1 3 3 -1 0 0 1 1 -1 0 2 0 -1 1 1 -1 1	-3 2 0 1 3 2 2 2 0 -1 0 -3 6 1 0 8 1 2 1 2 0 0 4 0 4 1 1 0 1 -1 1	-2 0 3 -4 1 1 2 2 -2 2 1 -3 5 3 8 0 2 3 1 0 -1 0 2 2 -1 1 -4 3 -2 1 1 3	-0 2 -1 1 2 -1 2 0 1 1 -1 3 3 1 2 0 2 2 1 -1 -2 0 0 0 -1 1 -2 1 0 1 2	1 2 1 -1 0 2 -1 1 3 2 1 0 -2 -1 2 3 2 0 -5 1 1 -1 -2 2 1 -1 -1 0 1 1 0	0 0 -1 2 0 0 -2 1 1 -2 1 0 0 1 2 -5 0 0 2 0 -1 5 -4 -1 0 3 0 -2 -3 0	0 0 0 2 3 1 0 -3 2 -1 2 2 1 0 2 0 1 1 0 0 1 1 2 3 1 -1 2 1 3 1 2 2	0 0 0 1 0 2 -1 0 1 1 1 -1 4 1 0 -1 1 2 1 0 0 -2 0 2 -3 2 0 3 -2 1 2	-2 1 2 0 0 0 0 -2 2 1 -2 0 -1 1 0 0 -2 -1 0 1 0 0 0 1 2 -1 1 1 2 1 1	1 -1 0 0 2 -2 0 0 1 0 0 1 3 -1 4 2 0 -2 1 2 -2 0 0 -1 3 0 1 -1 2 0 -1 0	0 0 2 1 1 2 2 1 1 -1 2 1 -3 0 0 -2 0 2 -5 3 0 1 -1 0 1 -1 0 1 0 0 2 0	0 1 2 2 2 -1 3 -2 -2 0 2 -3 0 2 4 -1 0 1 -4 1 2 2 3 1 0 1 2 -1 1 1 -1 1	1 1 0 -2 -1 0 -2 2 3 3 -1 1 -2 0 1 1 -1 -1 -1 -3 -1 0 -1 1 0 1 0 0 0 -2 2	0 -1 2 2 2 2 2 2 -1 1 -3 1 -2 1 1 -4 1 -1 0 2 2 -1 1 0 2 1 0 2 1 2 1 0	-1 1 0 -2 1 0 -1 1 -3 2 -2 1 5 1 0 3 -2 1 3 1 0 1 -1 1 -1 0 2 0 -1 0 -1 0	1 0 -2 -1 0 1 0 -2 2 1 -2 1 0 1 1 -2 1 0 0 0 3 -3 -1 2 0 1 0 1 -1 0 1 2 -1	-2 2 3 0 1 2 -1 1 0 -2 0 -1 0 1 -1 1 0 1 -2 1 -2 2 0 0 1 0 2 0 1 0 1 0 -1	0 0 -1 1 1 1 -1 1 -1 1 1 0 1 1 1 1 3 2 -1 1 -1 2 -1 2 1 1 2 0 0 0 0 0	-2 1 1 2 1 -1 2 -2 1 -3 1 2 2 -1 1 3 2 0 0 2 2 1 0 0 1 2 0 0 1 -1 0 0

channel048
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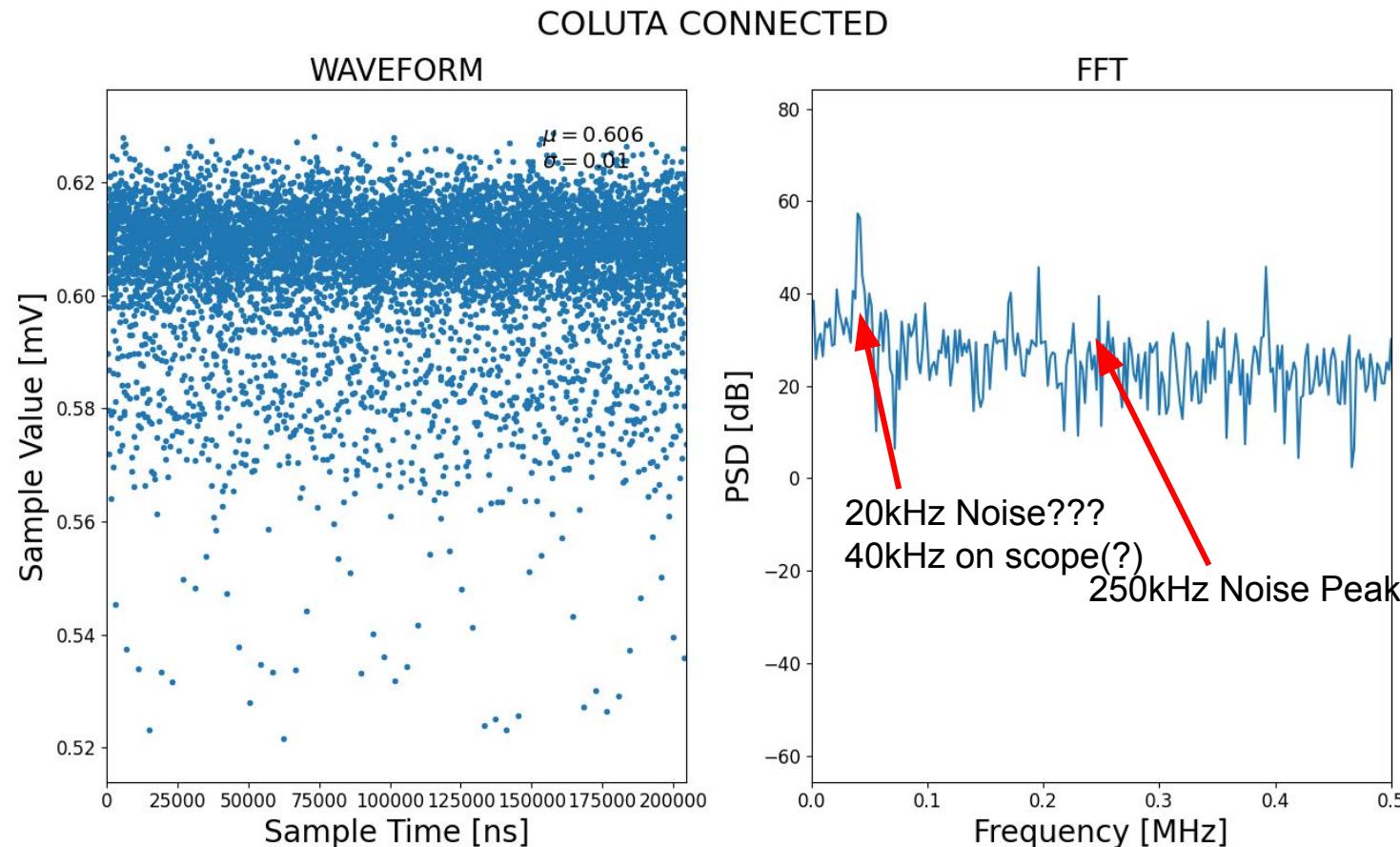
Probe LAUROC Outputs with Diff. Scope Directly, See Impact of 40MHz Sampling when COLUTA Connected



Probe LAUROC Outputs with Diff Scope when no COLUTA Connected, Smaller 40MHz Impact

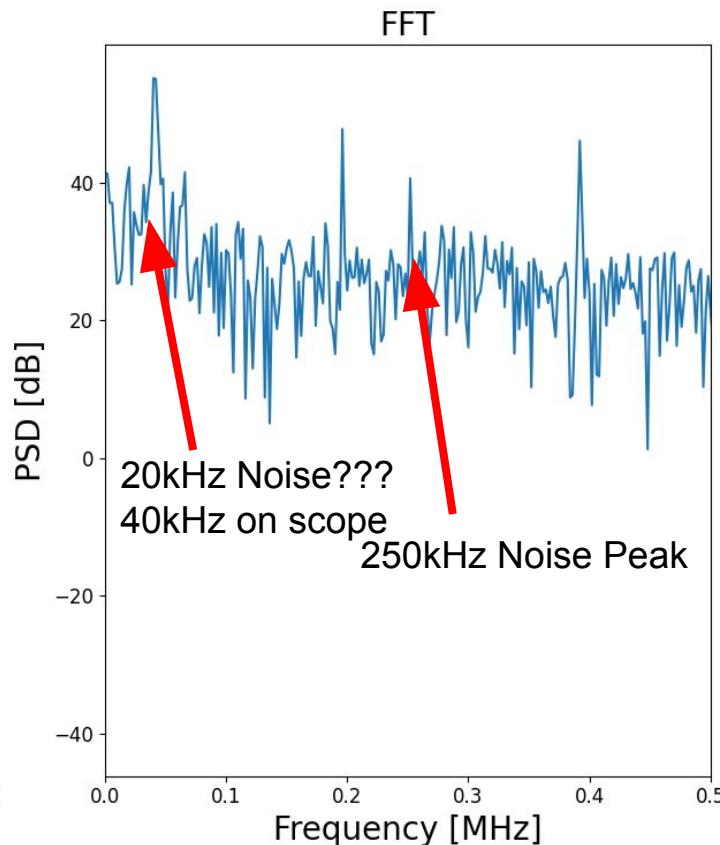
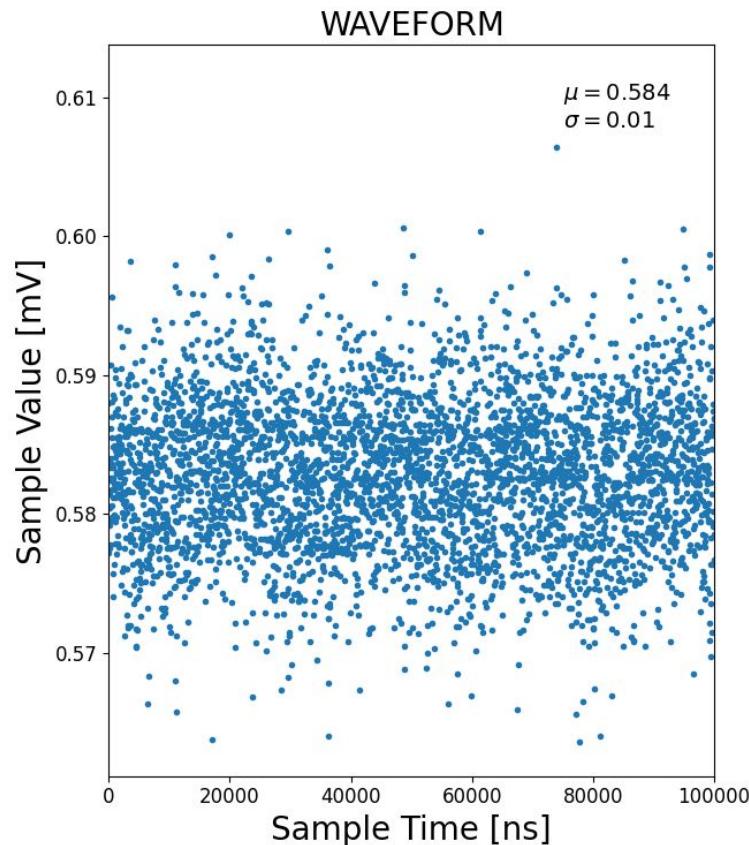


250kHz+20kHz(?) Noise Visible on LAUROC Outputs with Diff. Scope and COLUTA Connected



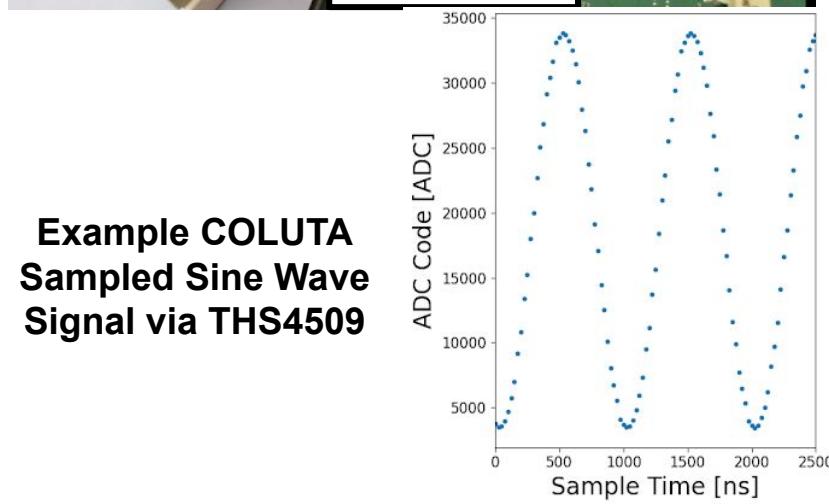
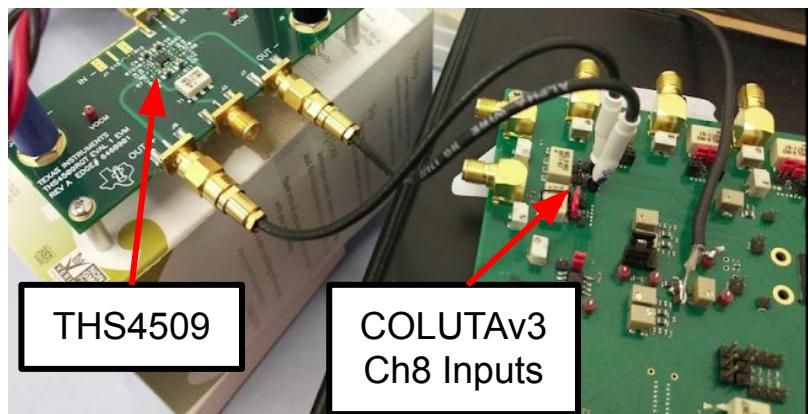
250kHz+20kHz(?) Noise Visible on LAUROC Outputs with Diff Scope and No COLUTA Connected

COLUTA NOT CONNECTED



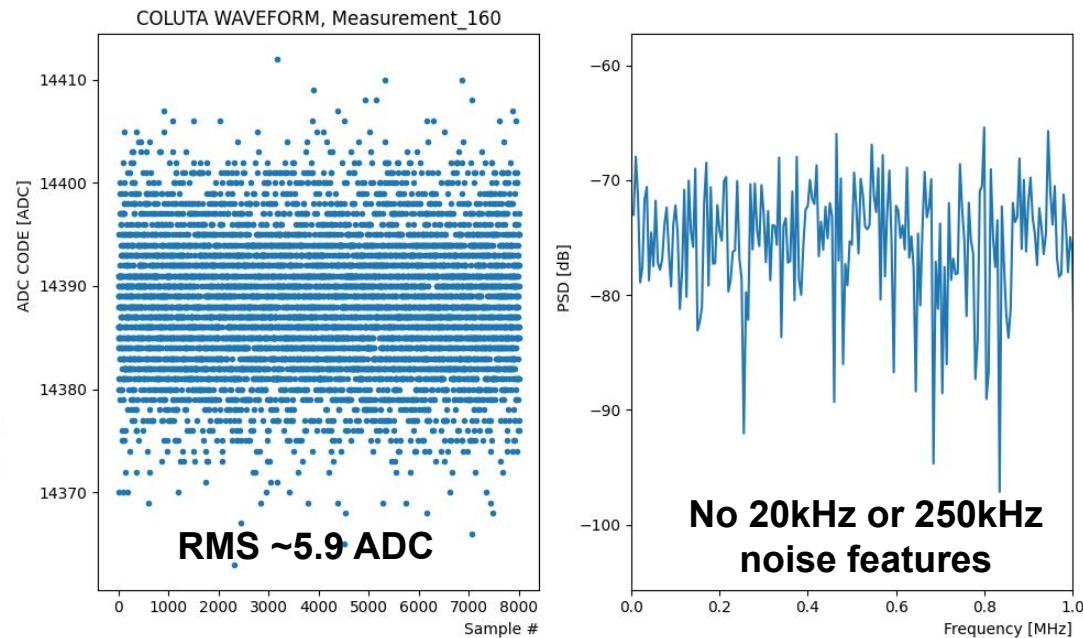
COLUTAv3 MDAC Input Driven by THS4509 PA

THS4509 injecting Sine Wave to COLUTA Ch



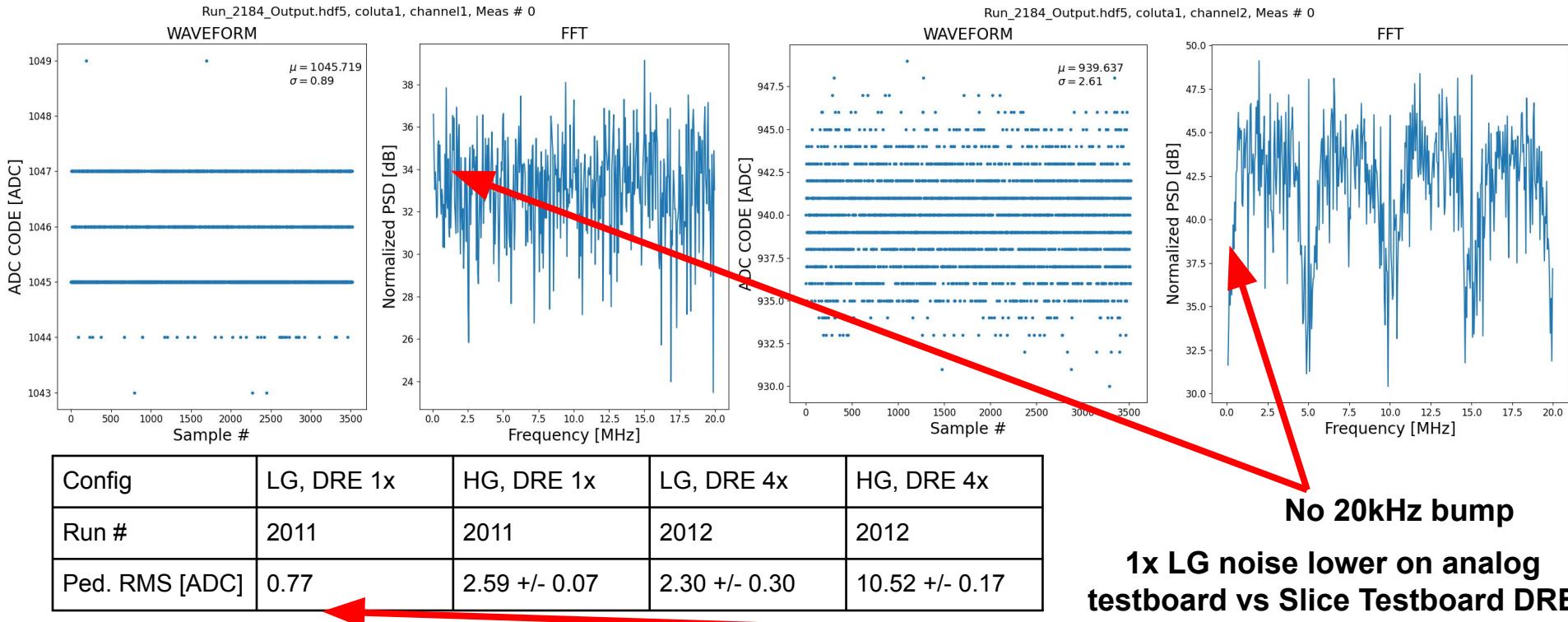
Example COLUTA
Sampled Sine Wave
Signal via THS4509

THS4509 into CV3 Board Ch8 Waveform+FFT



- Tried driving COLUTAv3 with THS4509 on Cv3 testboard as a comparison
- Do not see 20kHz “bump”

Reminder: Analog Testboard Noise Measurements



- Analog Testboard used LAUROC1 + COLUTAv2 (all DRE chs)
 - For COLUTAv2 only difference was using DRE channels with larger input capacitance
- No obvious 20 kHz “bump” in FFTs, correlated noise < 5%

1x LG noise lower on analog testboard vs Slice Testboard DRE

Chs (0.77ADC vs 1.5ADC)

Summary of Slice Testboard Noise Issues

- Pedestal noise measurements with Slice Testboard (that uses 8 LAUROC2 chips connected to 8 COLUTAv3 ADC chips) show some issues:
 - Individual channels seem significantly noisier than expected (particularly apparent for LO gain)
 - Coherent noise across channels is significantly higher than <5% specification and what was achieved previously with Analog Testboard (using LAUROC1 and COLUTAv2)
- Two main noise features observed: 250kHz line and 20kHz “bump”
- **250kHz noise** from onboard DC/DC converters
 - COLUTA channel not connected to LAUROC does not see 250kHz noise
 - Can be removed using external PS
 - Scope shows 250kHz noise on LAUROC outputs, even when COLUTA not connected
- **20kHz noise:**
 - Appears to be correlated across board halves
 - Opposite phase between LG and HG channels
 - COLUTA channel not connected to LAUROC does not see 20kHz noise
 - Not removed using the external PS
 - Noise remains when PA, G20 and S1 disabled
 - Not removed by adding 50Ohm series resistors to LAUROC outputs
 - Can be removed by adjusting LAUROC DAC VDC HG/LG to low values ie. <5 counts
 - Scope might show 20kHz noise on LAUROC outputs, even with COLUTA disconnected (???)
 - Not seen in Analog Testboard or Cv3 testboard + THS4509 sampled waveforms

Some questions for PA/S team

- For open input (or for some fixed Cdet), what are the measured and expected LAUROC noise levels (in muV) at output of HI and LO gain shapers?
- Do you see 20 kHz noise feature on your dedicated LAUROC (or ALFE) testboards?
 - If not, do you think your measurements would be sensitive to its presence?
 - What ADC are you using to digitize the PA/S output signals?
- Have you measured LAUROC output noise as a function of the DAC VDC used to set the shaper output baseline voltage?
- Is anti-correlation between HI and LO 20 kHz noise related to the fact that DAC VDC value moves HI and LO baseline voltages in opposite directions?
- Any ideas about source of (20 kHz) correlated noise, and how to mitigate and/or remove it?
- What would these results imply with regard to expectations for ALFE2?

BACKUP

From March 2021 LAr-Week:

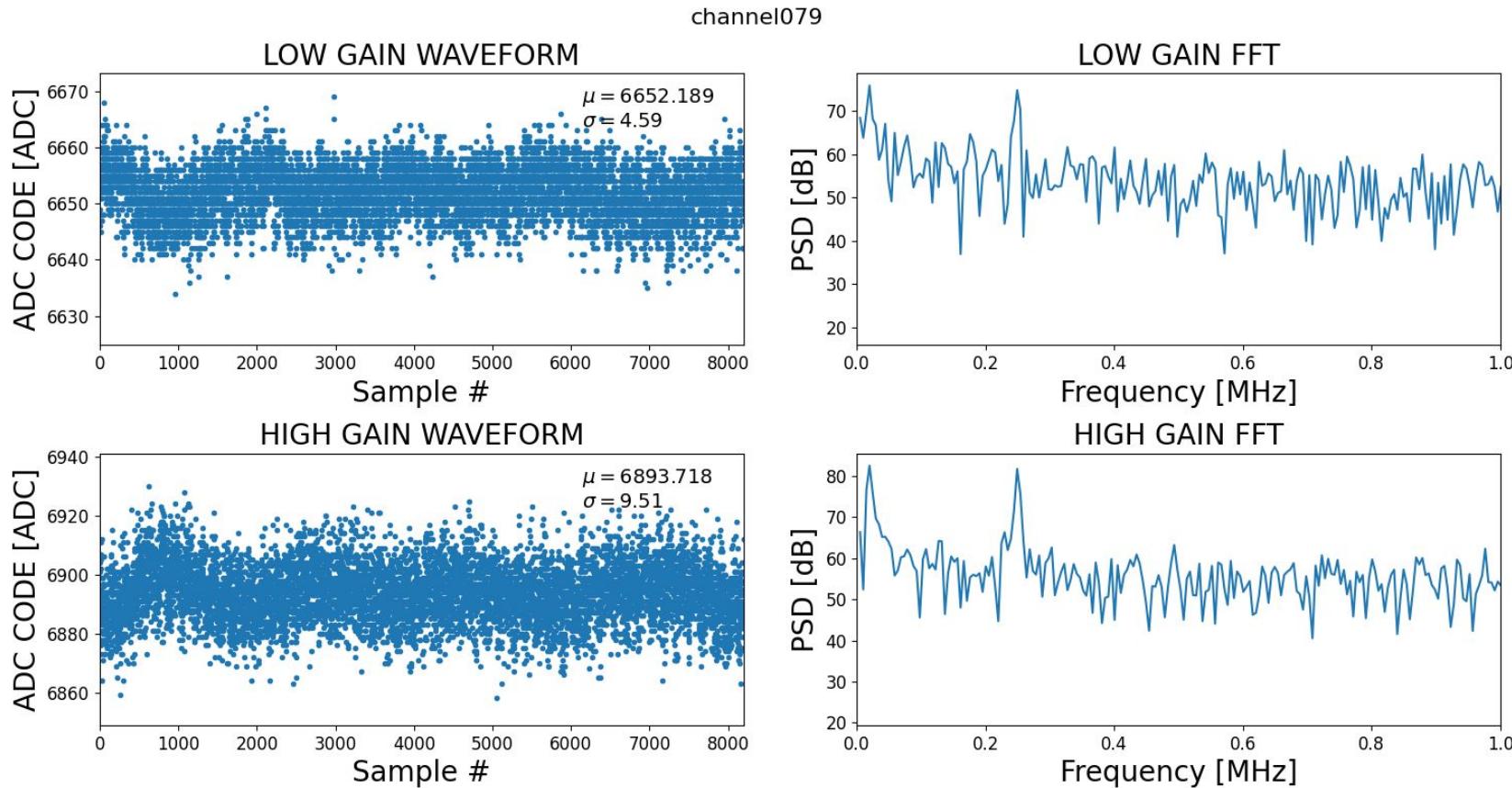
Investigating 20 kHz Noise

We have so far tried a number of modifications to the board to see if we could isolate the source of the 20 kHz noise:

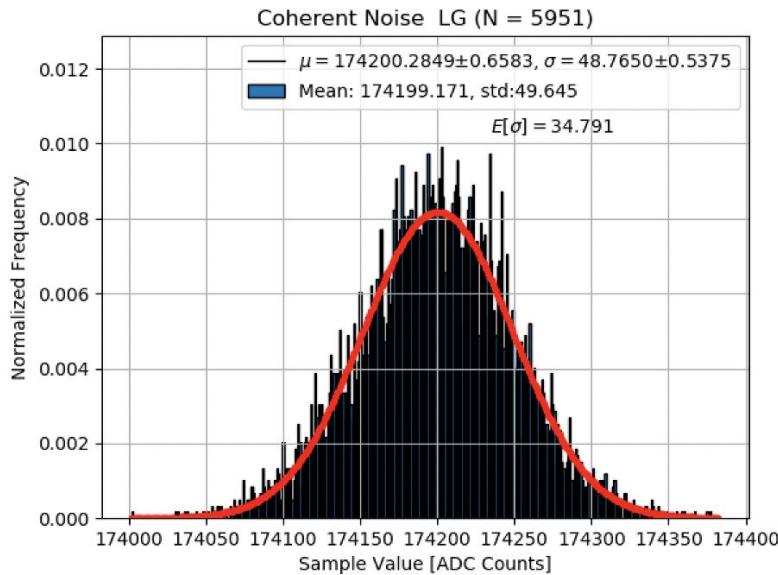
- Adding a Faraday cage over the input connectors
- Adding a Faraday cage over the preamps
- Shorting the signal input pins
- Disabling the PA/S 40 MHz clock
- Removing the AC-coupling capacitor in the input protection networks, in order to disconnect the PA/S input
- Partially disabling the preamp
 - $ON_pa=0, ON_g20=1, ON_lg_s1=1, ON_hg_s1=1, ON_lg_s2=1, ON_hg_s2=1$
 - $ON_pa=0, ON_g20=0, ON_lg_s1=1, ON_hg_s1=1, ON_lg_s2=1, ON_hg_s2=1$
 - $ON_pa=0, ON_g20=0, ON_lg_s1=0, ON_hg_s1=0, ON_lg_s2=1, ON_hg_s2=1$

The 20kHz noise remained roughly consistent through all these tests

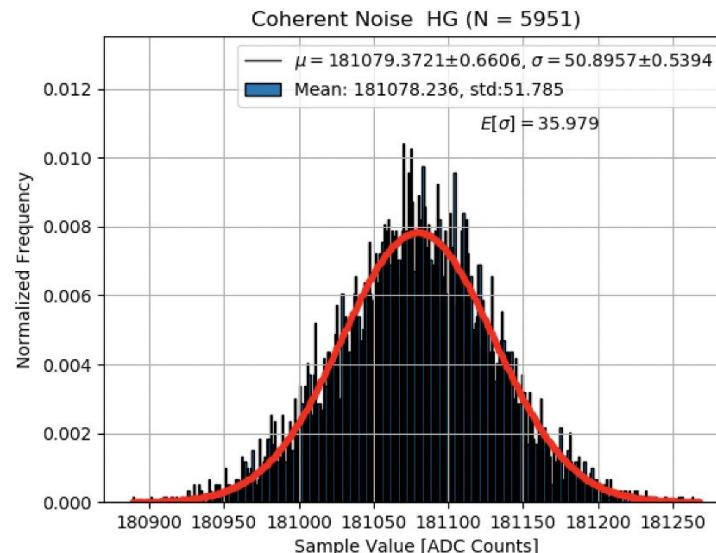
Slice Testboard Noise Features, 8192 Sample Readout



Correlated Noise Measurement

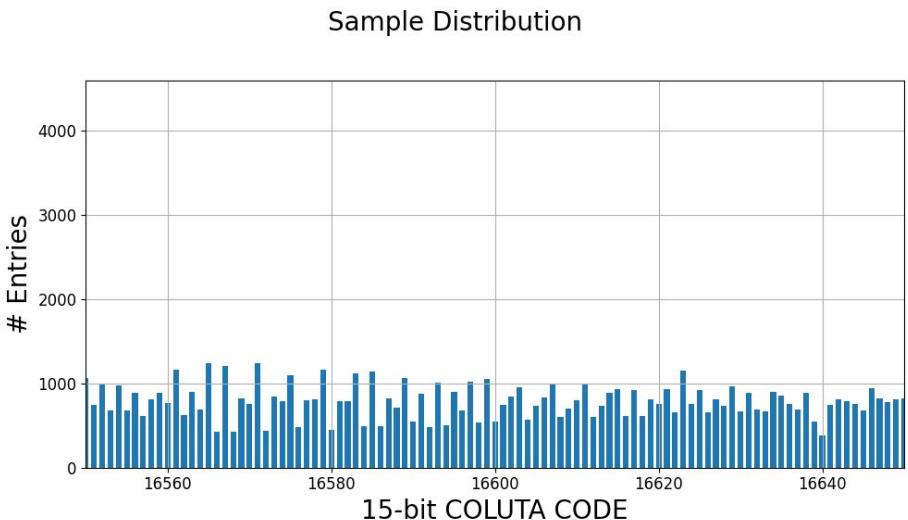
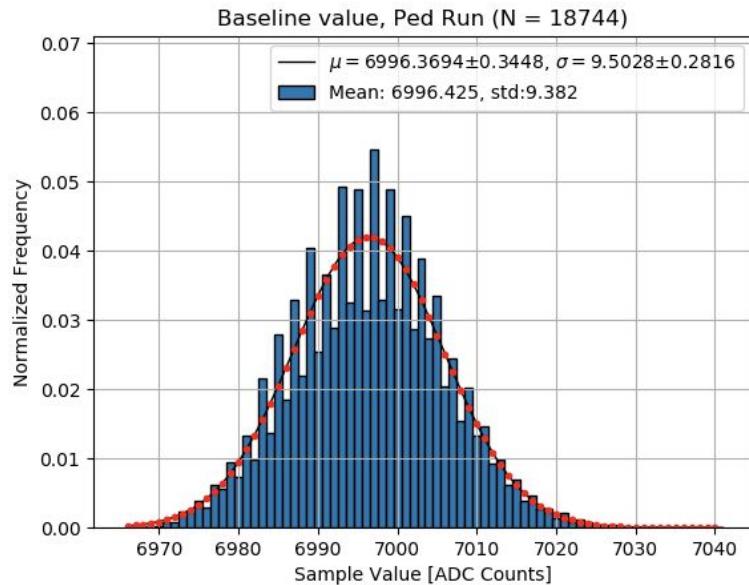


$$\text{Sqrt}(\text{sig}^2 - E[\text{sig}]^2) = 34.2 \text{ cts}$$



$$\text{Sqrt}(\text{sig}^2 - E[\text{sig}]^2) = 36.0 \text{ cts}$$

Even/Odd Effect, Not Related to 250kHz/20kHz Noise



20kHz Noise Appears When DAC VDC > 5 Counts

DACB HG	DACB LG	Run	HG BL [ADC]	LG BL [ADC]	HG RMS [ADC]	LG RMS [ADC]	LG 20kHz Noise Peak wrt Noise Floor	HG 20kHz Noise Peak wrt Noise Floor
62	32	310	7190	6570	9.0	5.2	25dB	35dB
0	0	313	Underflow	11860	7.9	3.9	3dB	3dB
5	5	326	Underflow	10952	7.7	3.5	8dB	8dB
10	10	324	223	10400	7.8	4.45	12.5dB	13dB
15	15	315	950	9500	7.6	4.6	15dB	13dB
31	31	317	2970	6650	8.2	5.5	22.1dB	20.5
48	48	319	5470	4070	8.6	5.9	22B	23dB
63	63	322	7320	1790	9.2	7.3	28dB	28dB

Noise Features Remain with LAUROC Clocks OFF

