Studies on undershoot mitigation for DAPHNE and improvements in SNR in DAPHNE V2A

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Content

- Improvements in DAPHNE V2A
- Grounding issues seen during test.
- Undershoot mitigation in DAPHNE V2A

IMPROVEMENTS IN DAPHNE V2A

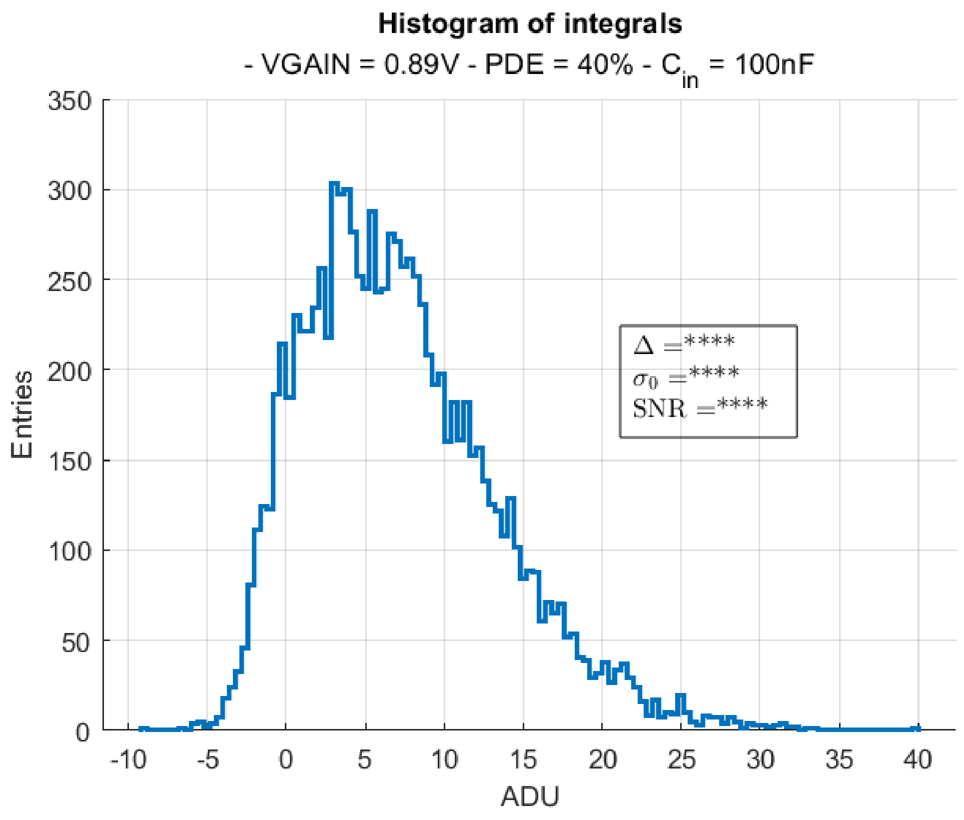
TEST CONDITIONS

- The test were perfomed on FBK-3T SiPMs for:
  - 40% PDE.
  - 45% PDE.
  - 50% PDE.
- DAPHNE performance was compared using the SNR figure of merit with:
  - Charge filter (presented in previous meeting; the same implemented insed the FPGA for self-triggering)
  - Deconvolution filter: currently in development process, here analysis done independently by F. Galizzi.
- Integrators ON and OFF are compared.
- Signal spectrum is compared with 2m cable and 30m warm cable.
- Same conditions for DAPHNE V2A and V1:
  - VGAIN: 0.89V; LNAG: 12dB; PGAG: 24dB.
  - 30000 waveforms of length 2048.

SNR Comparison – FBK 40% PDE

Integrators OFF

DAPHNE V1



Improvement

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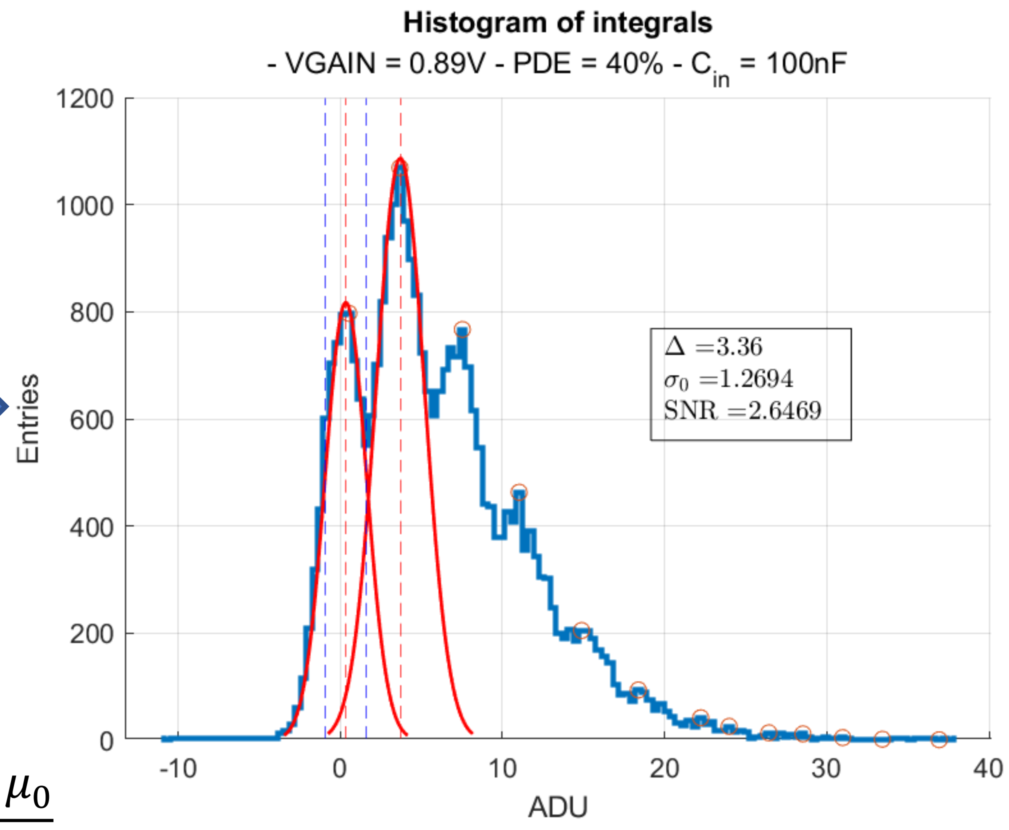
DAPHNE V2A

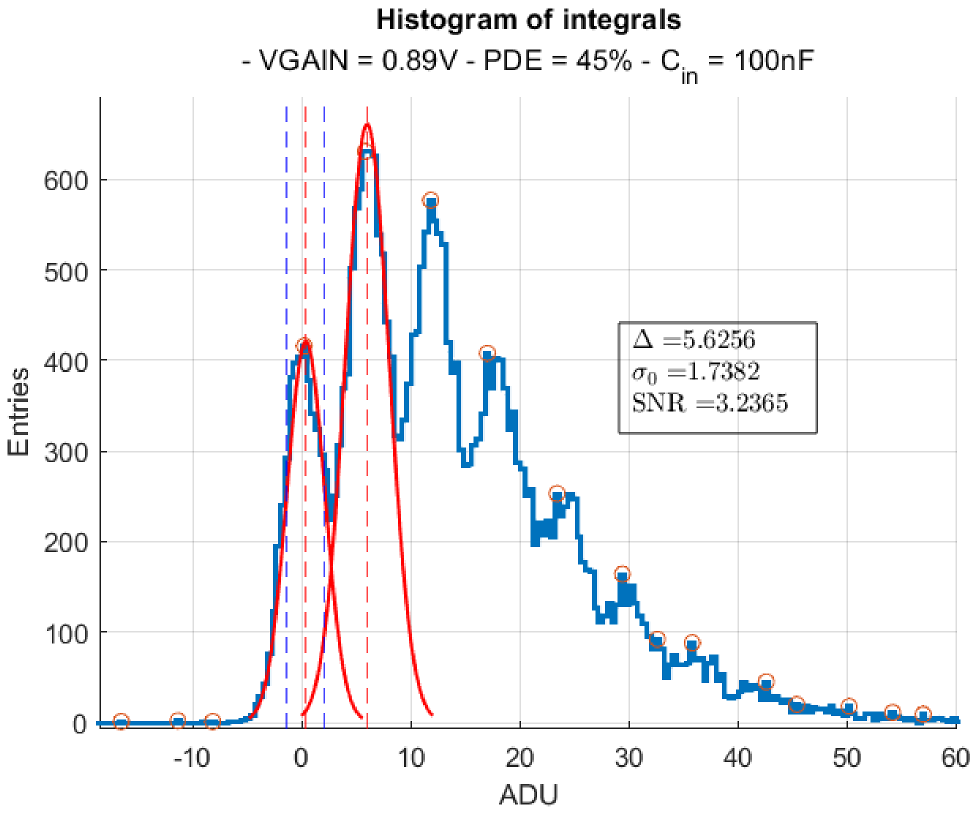


$$SNR = \frac{\Delta}{\sigma_0} = \frac{\mu_1 - \mu_0}{\sigma_0}$$

SNR Comparison – FBK 45% PDE

Integrators OFF

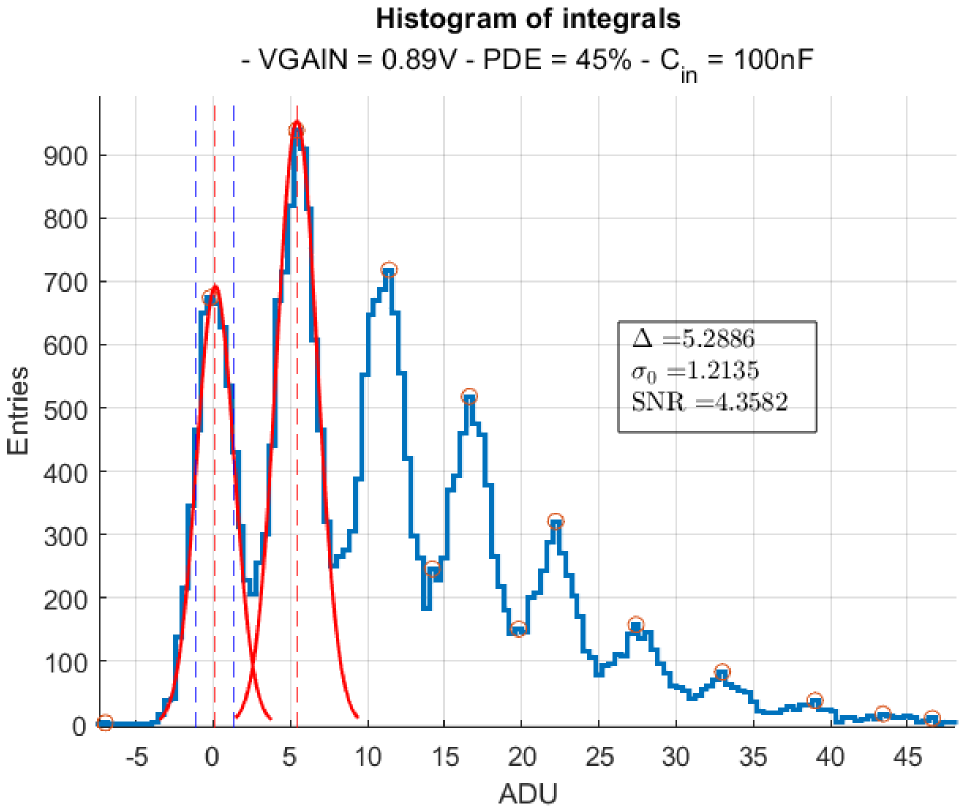
DAPHNE V1



Improvement

34.66%

DAPHNE V2A

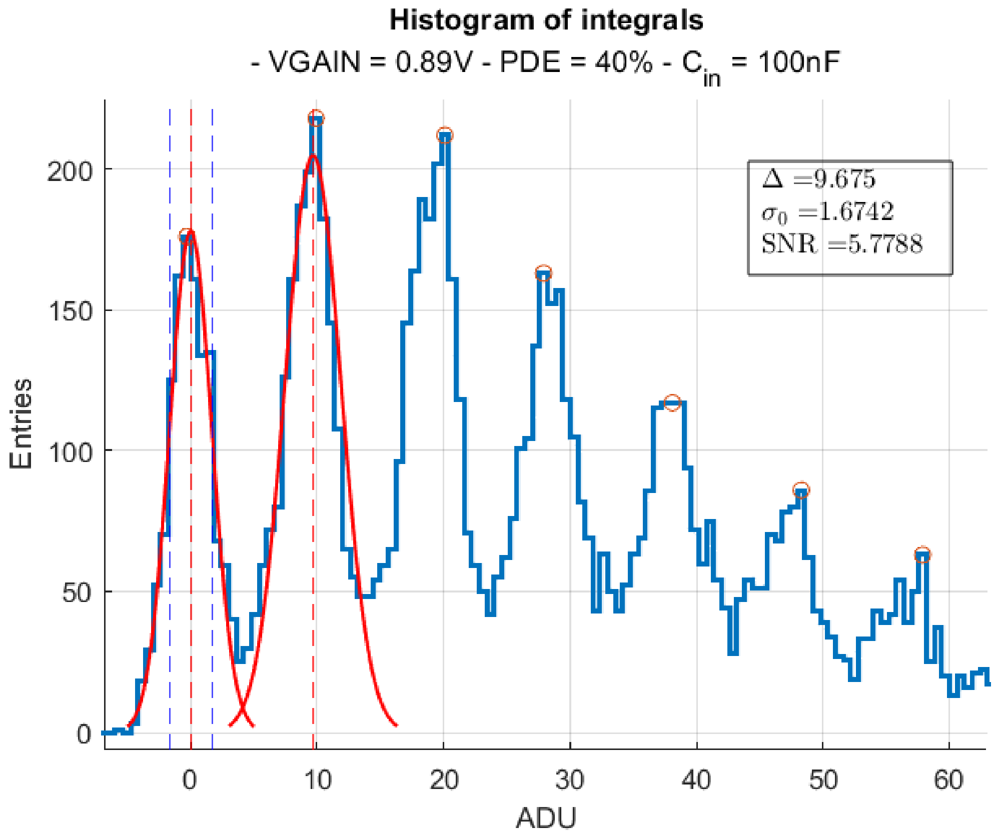


$$SNR = \frac{\Delta}{\sigma_0} = \frac{\mu_1 - \mu_0}{\sigma_0}$$

SNR Comparison – FBK 50% PDE

Integrators OFF

DAPHNE V1

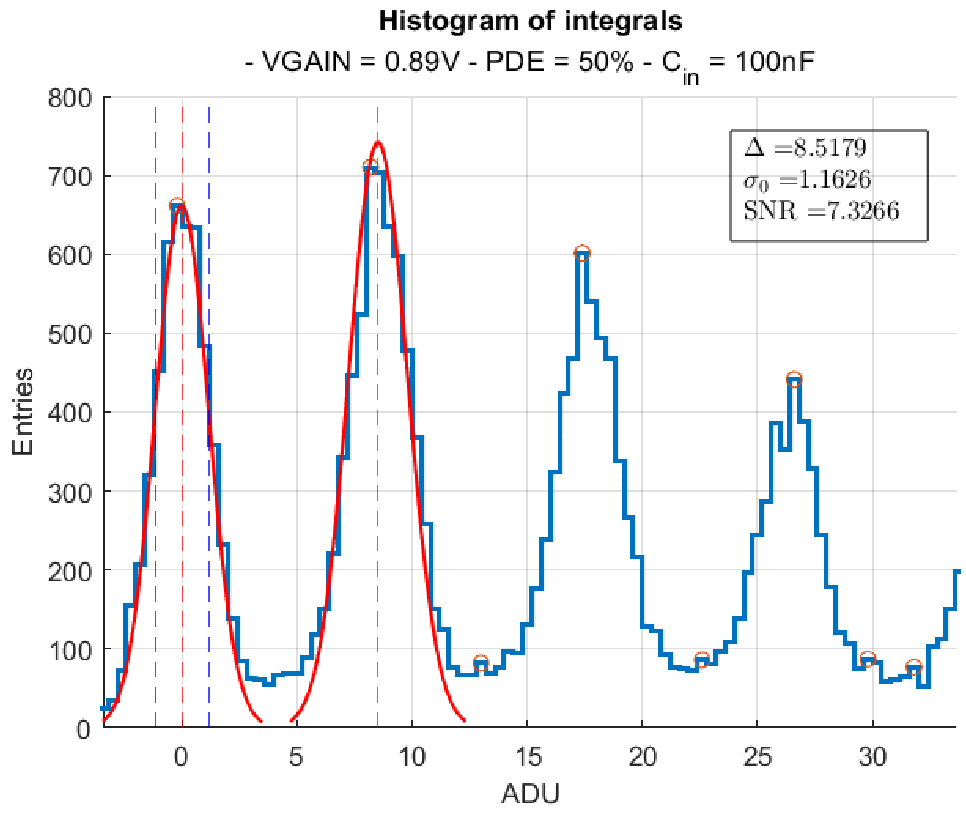


Improvement

26.78%

$$SNR = \frac{\Delta}{\sigma_0} = \frac{\mu_1 - \mu_0}{\sigma_0}$$

DAPHNE V2A



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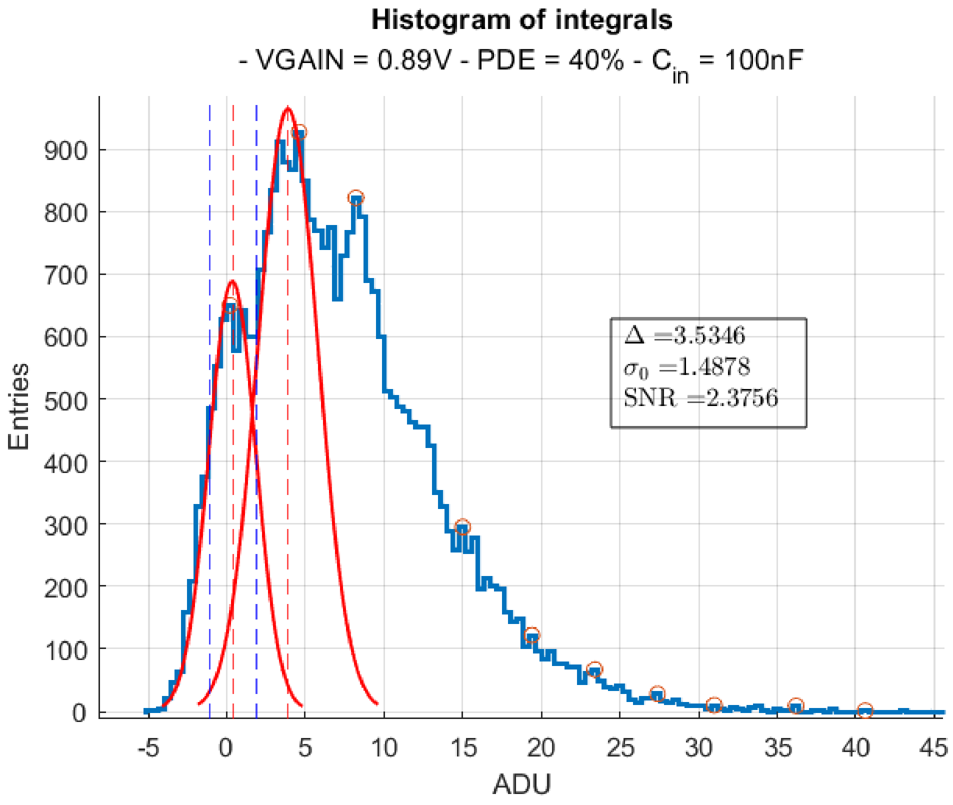
SNR Comparison – FBK 40% PDE

Integrators ON

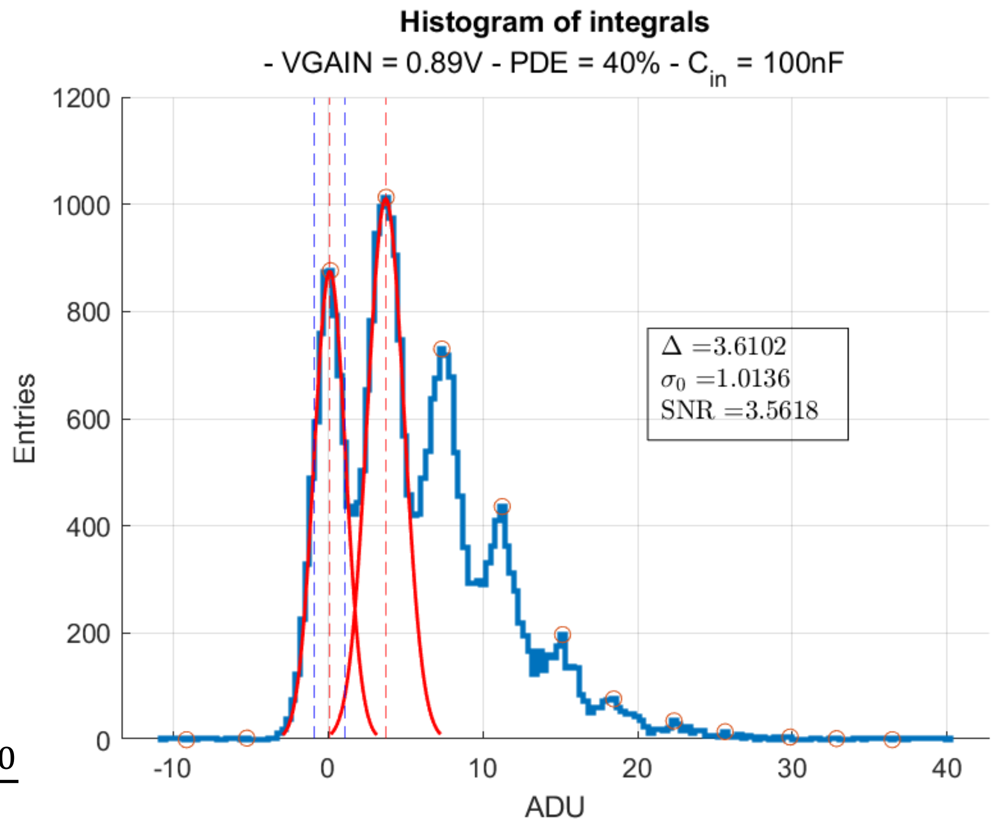
DAPHNE V1



Improvement

49.93% *

DAPHNE V2A

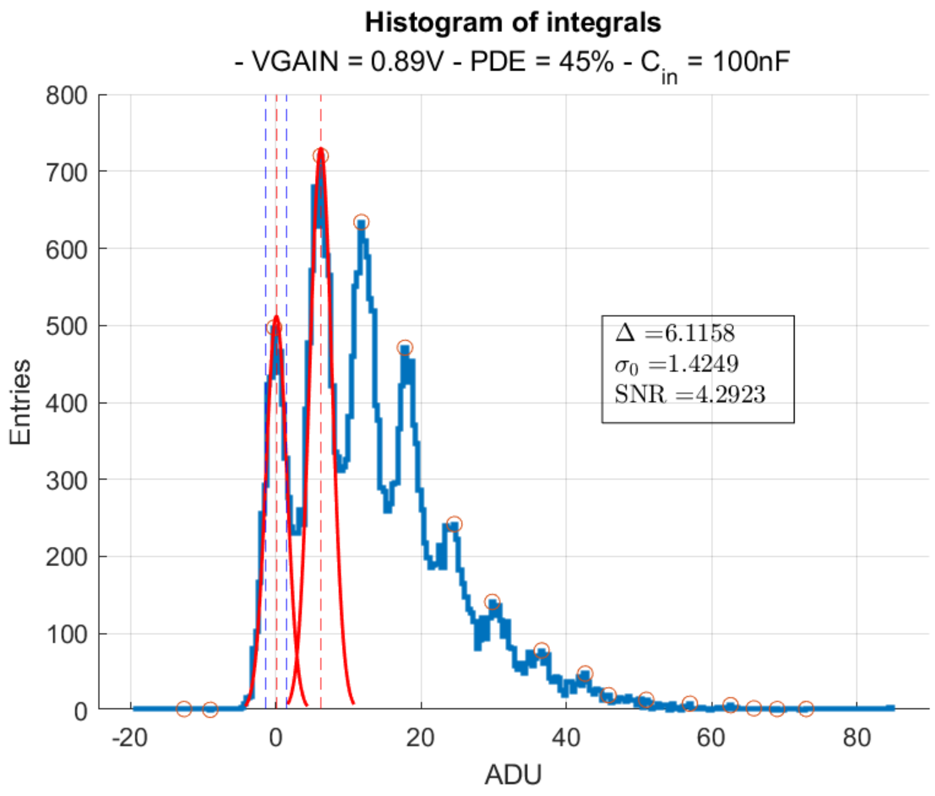


$$SNR = \frac{\Delta}{\sigma_0} = \frac{\mu_1 - \mu_0}{\sigma_0}$$

SNR Comparison – FBK 45% PDE

Integrators ON

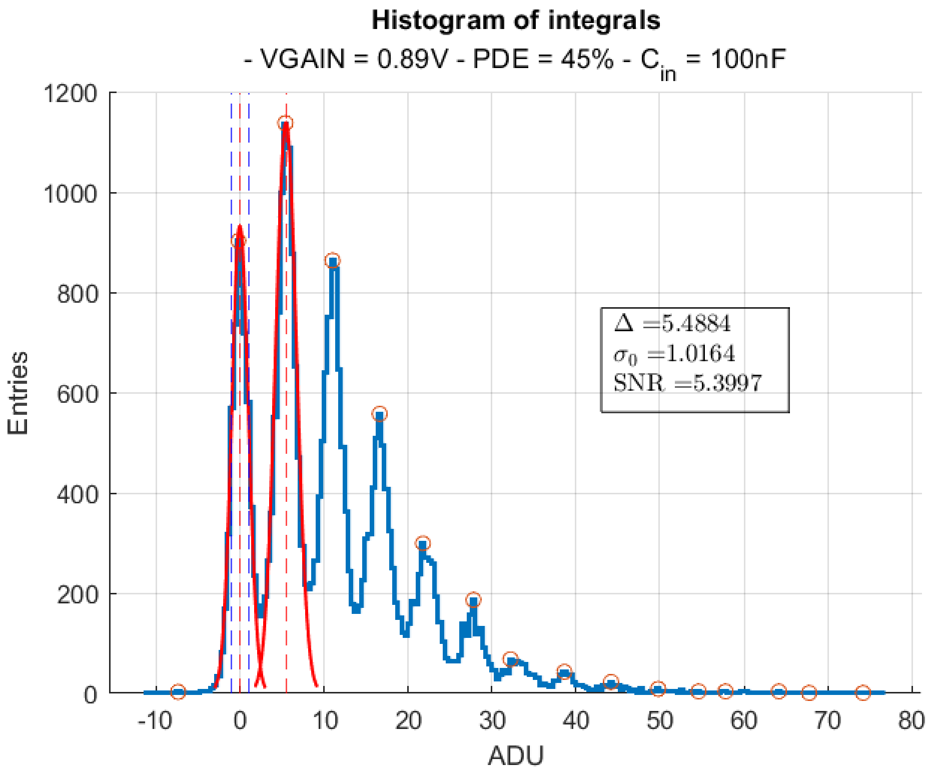
DAPHNE V1



Improvement

25.8%

DAPHNE V2A

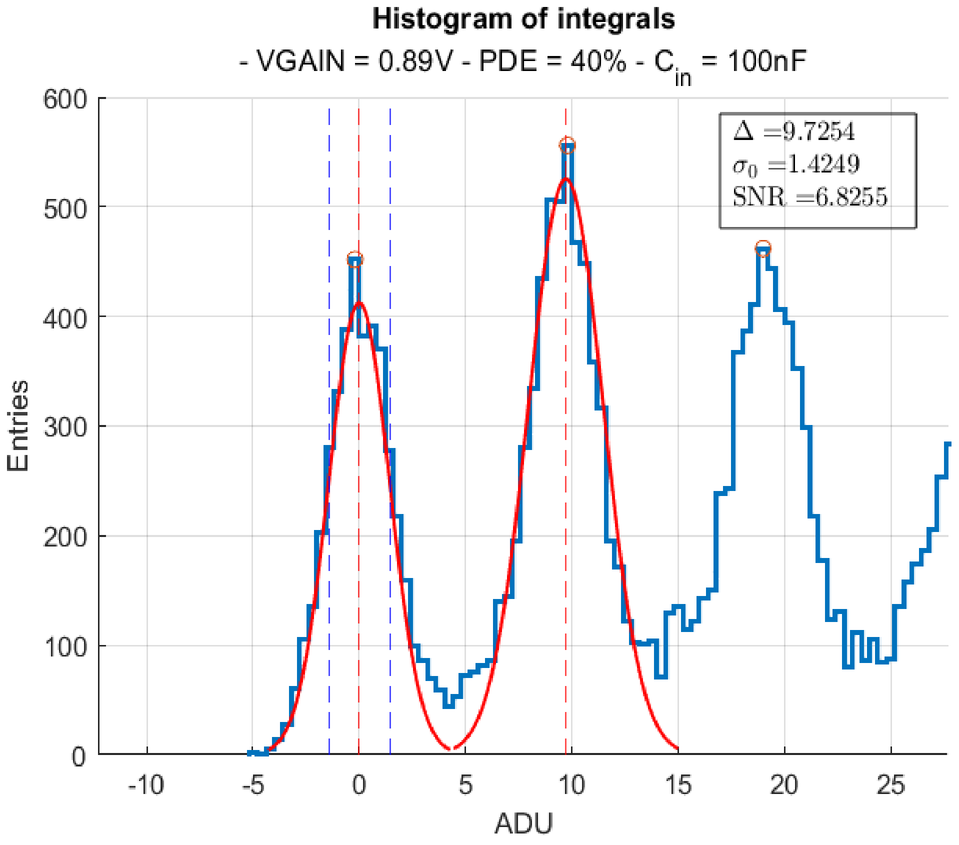


$$SNR = \frac{\Delta}{\sigma_0} = \frac{\mu_1 - \mu_0}{\sigma_0}$$

SNR Comparison – FBK 50% PDE

Integrators ON

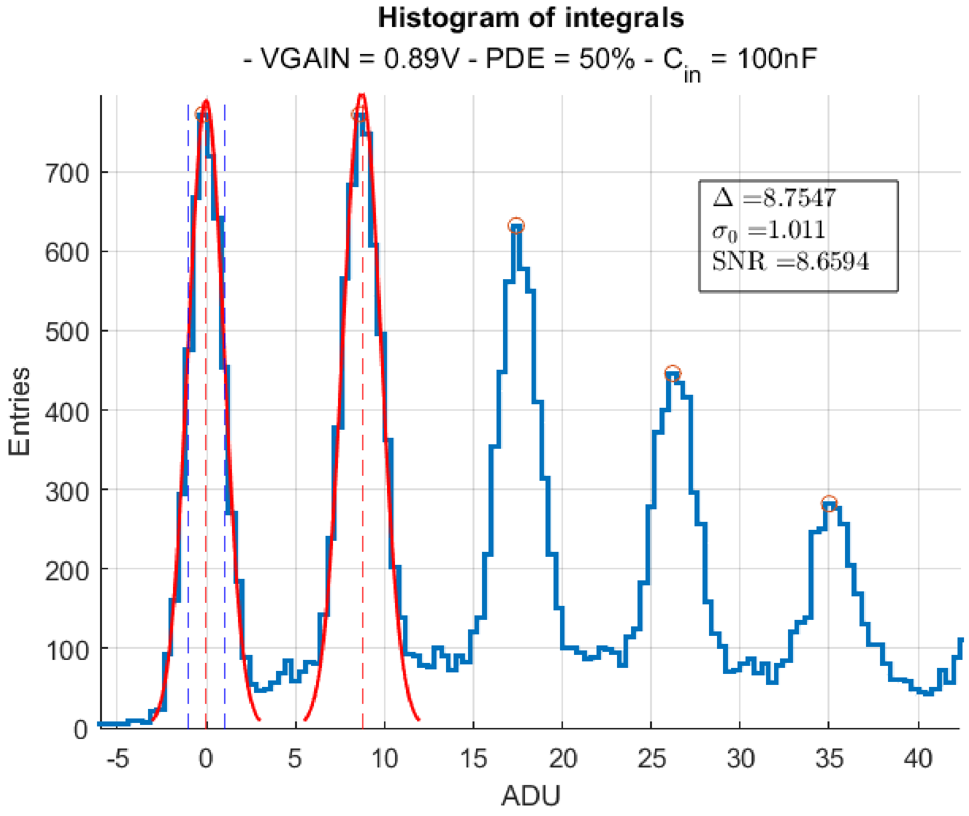
DAPHNE V1



Improvement

26.87%

DAPHNE V2A

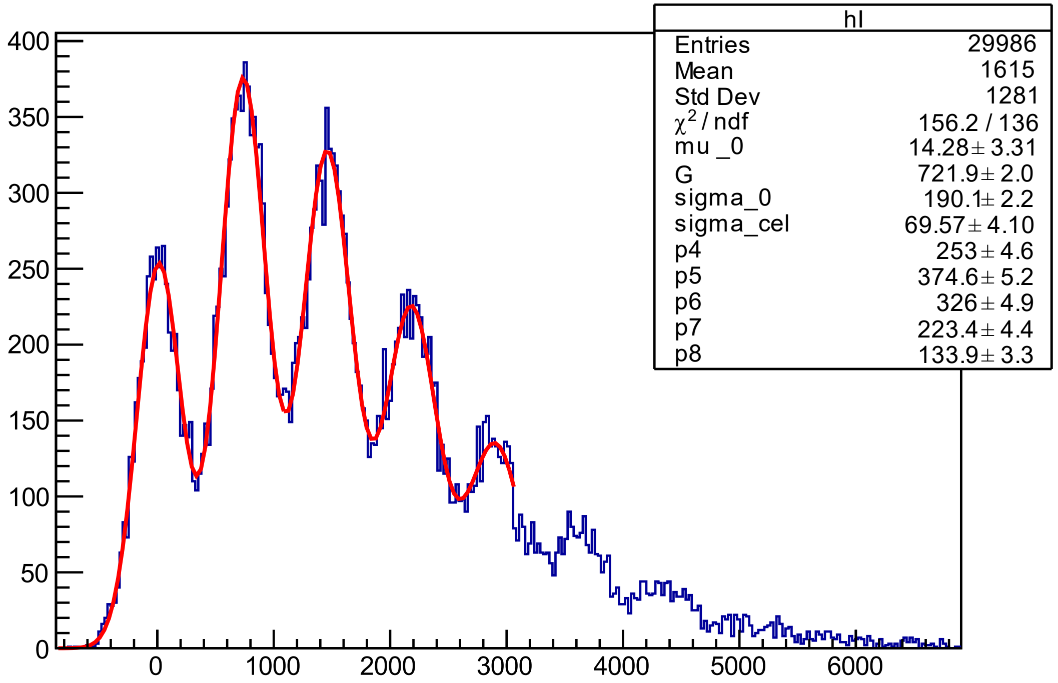


$$SNR = \frac{\Delta}{\sigma_0} = \frac{\mu_1 - \mu_0}{\sigma_0}$$

SNR Comparison – FBK 45% PDE DECONVOLUTION METHOD

Integrators OFF

DAPHNE V1



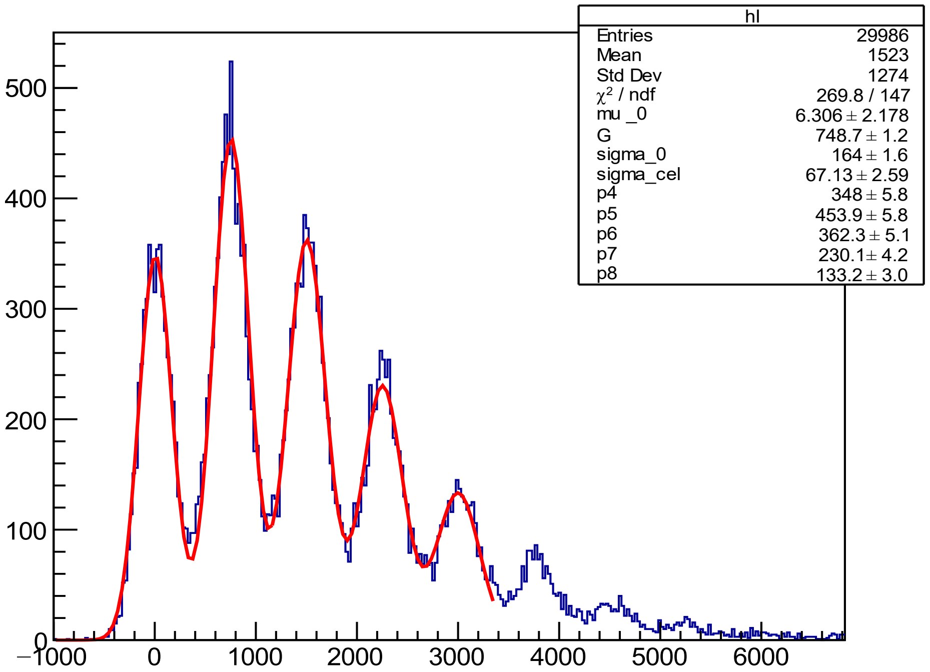
$$SNR = \frac{G}{\sigma_0} = 3.7974$$

$$SNR = \frac{G}{\sigma_0}$$

Improvement

20.22%

DAPHNE V2A

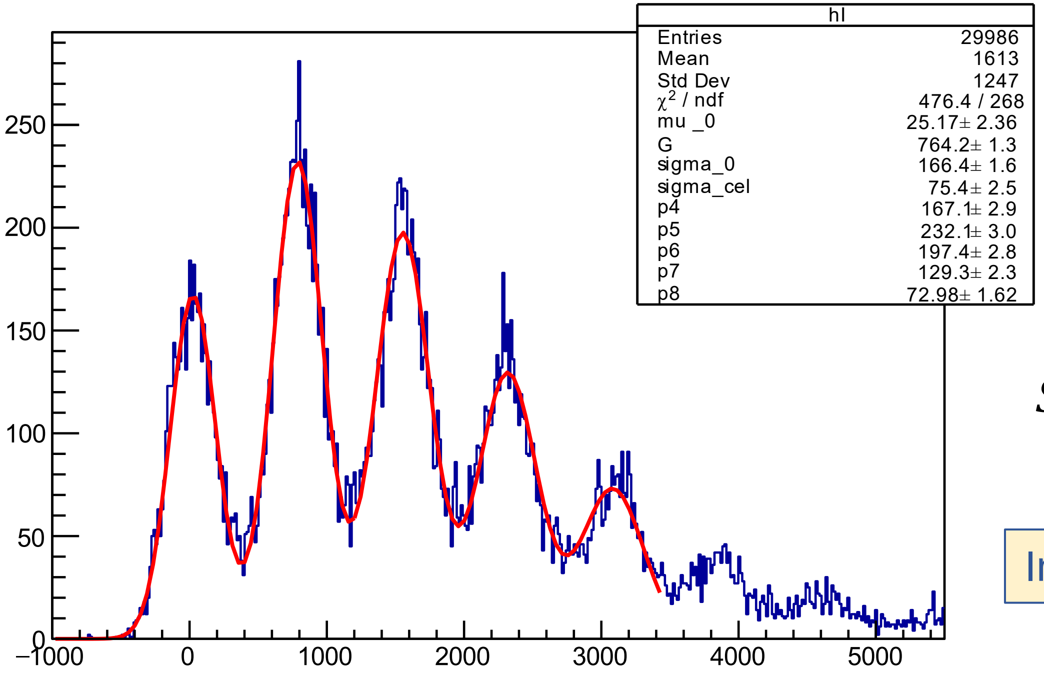


$$SNR = \frac{G}{\sigma_0} = 4.5652$$

SNR Comparison – FBK 45% PDE DECONVOLUTION METHOD

Integrators ON

DAPHNE V1



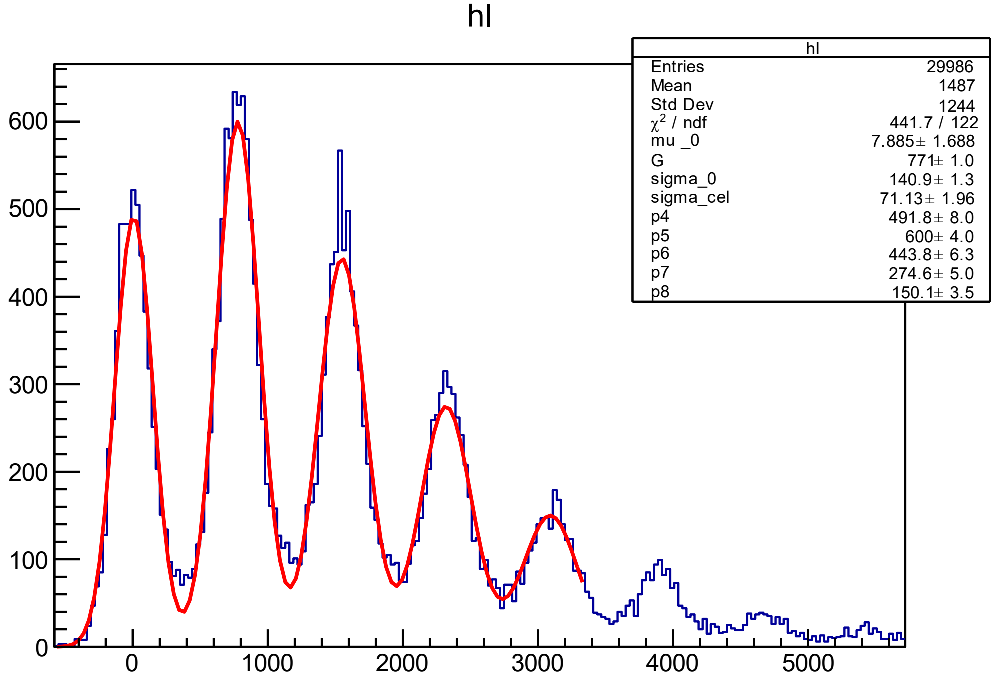
$$SNR = \frac{G}{\sigma_0} = 4.5925$$

$$SNR = \frac{G}{\sigma_0}$$

Improvement

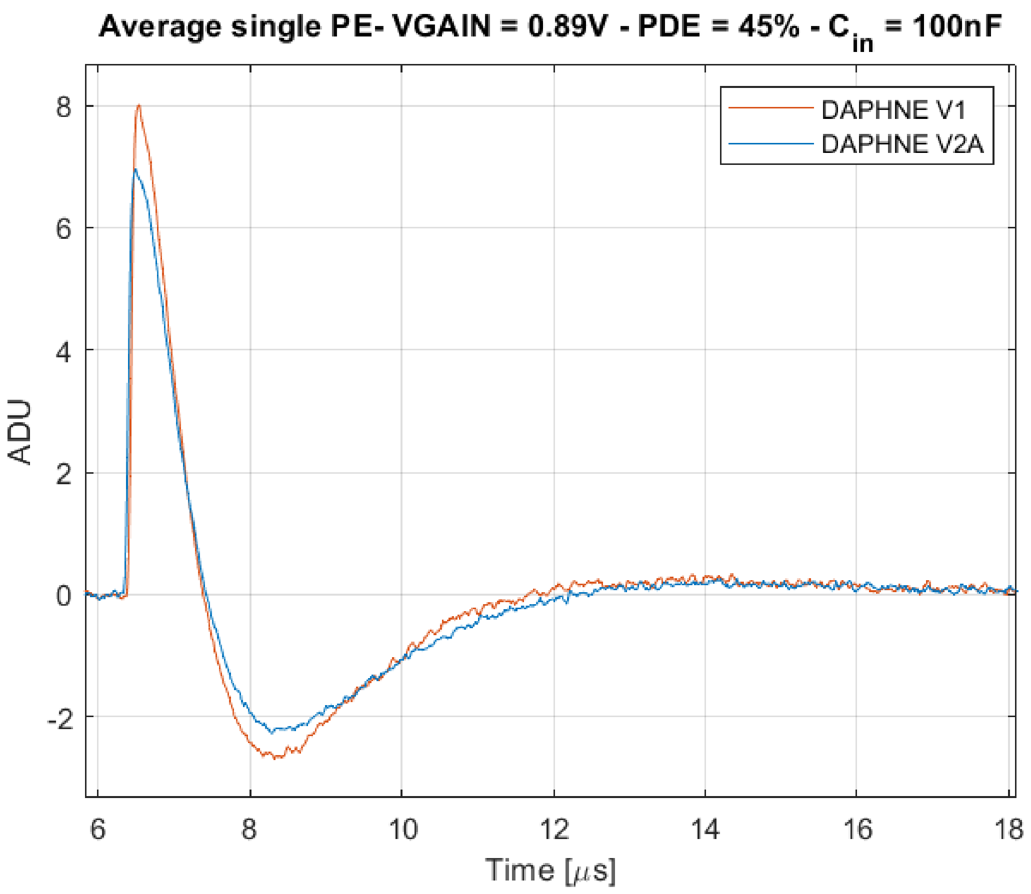
19.15%

DAPHNE V2A

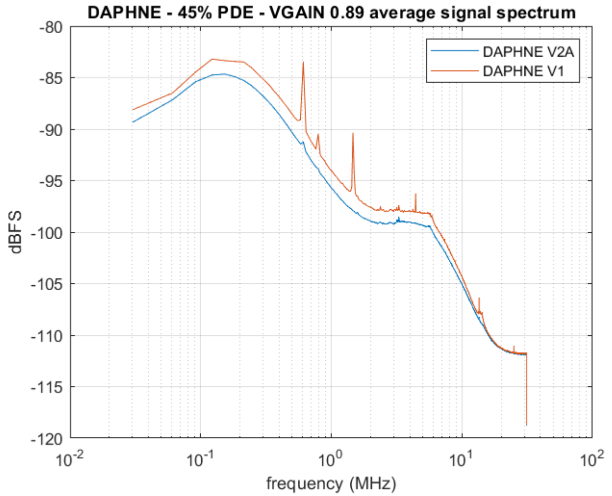


$$SNR = \frac{G}{\sigma_0} = 5.4719$$

Average Waveforms – FBK 45% PDE



Signal is attenuated ~1.37dB



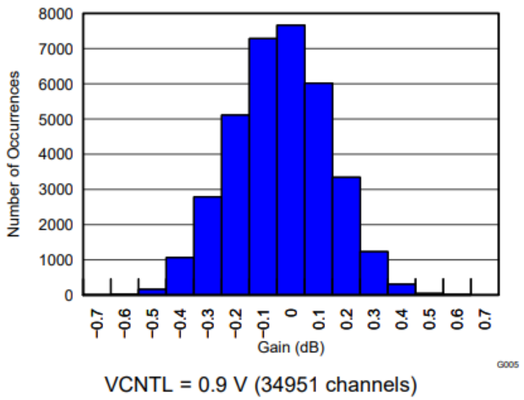


Figure 6. Gain Matching Histogram

- Gain Mismatch between DAPHNE V1 and DAPHNE V2A can be attributed to an intrinsic AFE channel gain mismatch, which can be up to 1dB and minor mismatch in the Vbias voltage calibration for each board AFE.
- The spectrum characteristics is not altered, other than a constant attenuation up to the filter cut-off frequency.

SNR Comparison – SUMMARY

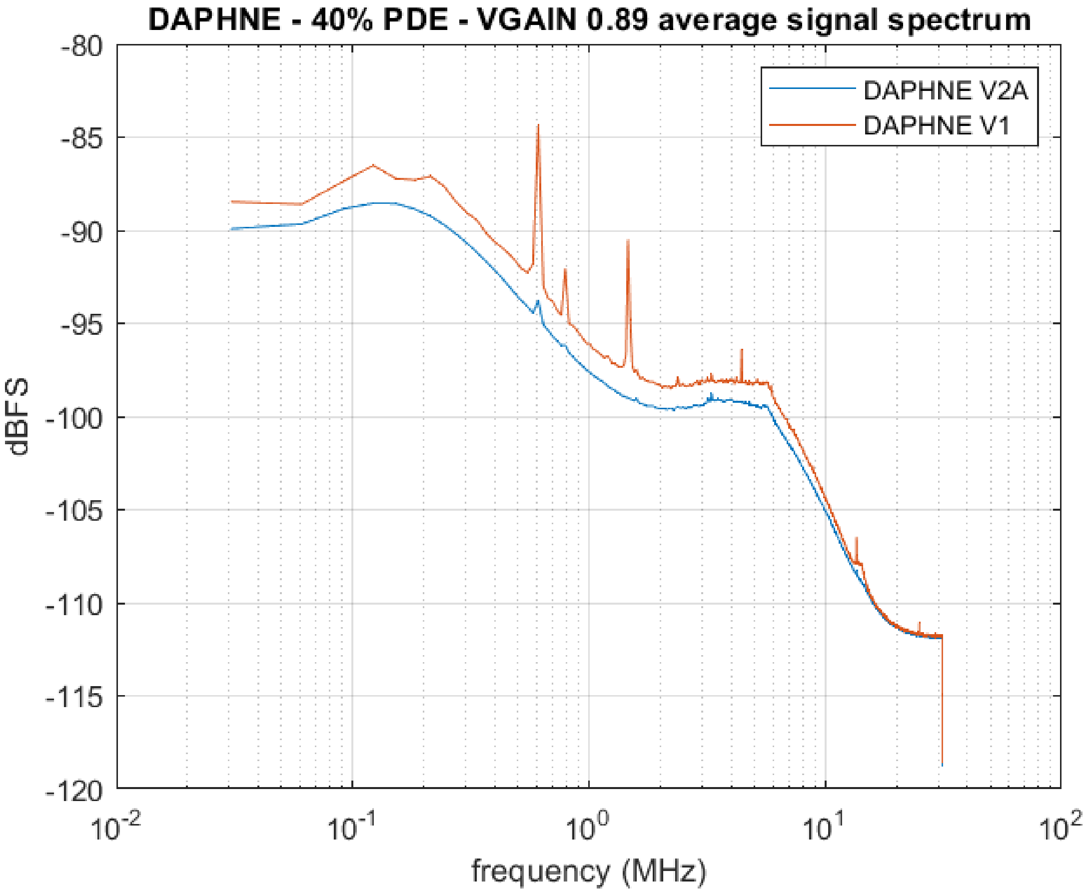
	DAPHNE V1				DAPHNE V2A			
	Integrator OFF		Integrator ON		Integrator OFF		Integrator ON	
PDE	Integrator Filter	Deconvolution Filter	Integrator Filter	Deconvolution Filter	Integrator Filter	Deconvolution Filter	Integrator Filter	Deconvolution Filter
40%	***	***	2.3756	2.7354	2.6469	2.9058	3.5618	3.9905
45%	3.2365	3.7974	4.2923	4.5925	4.3582	4.5652	5.3997	5.4719
50%	5.7788	***	6.8255	***	7.3266	***	8.6594	***

	Improvement from V1 to V2A (%)				Improvement in Analisis			
	Integrator OFF		Integrator ON		DAPHNE V1		DAPHNE V2A	
PDE	Integrator Filter	Deconvolution Filter	Integrator Filter	Deconvolution Filter	Integrator OFF	Integrator ON	Integrator OFF	Integrator ON
40%	***	***	49.93	45.88	***	15.15	9.78	12.04
45%	34.66	20.22	25.80	19.15	17.33	6.99	4.75	1.34
50%	26.78	***	26.87	***	***	***	***	***

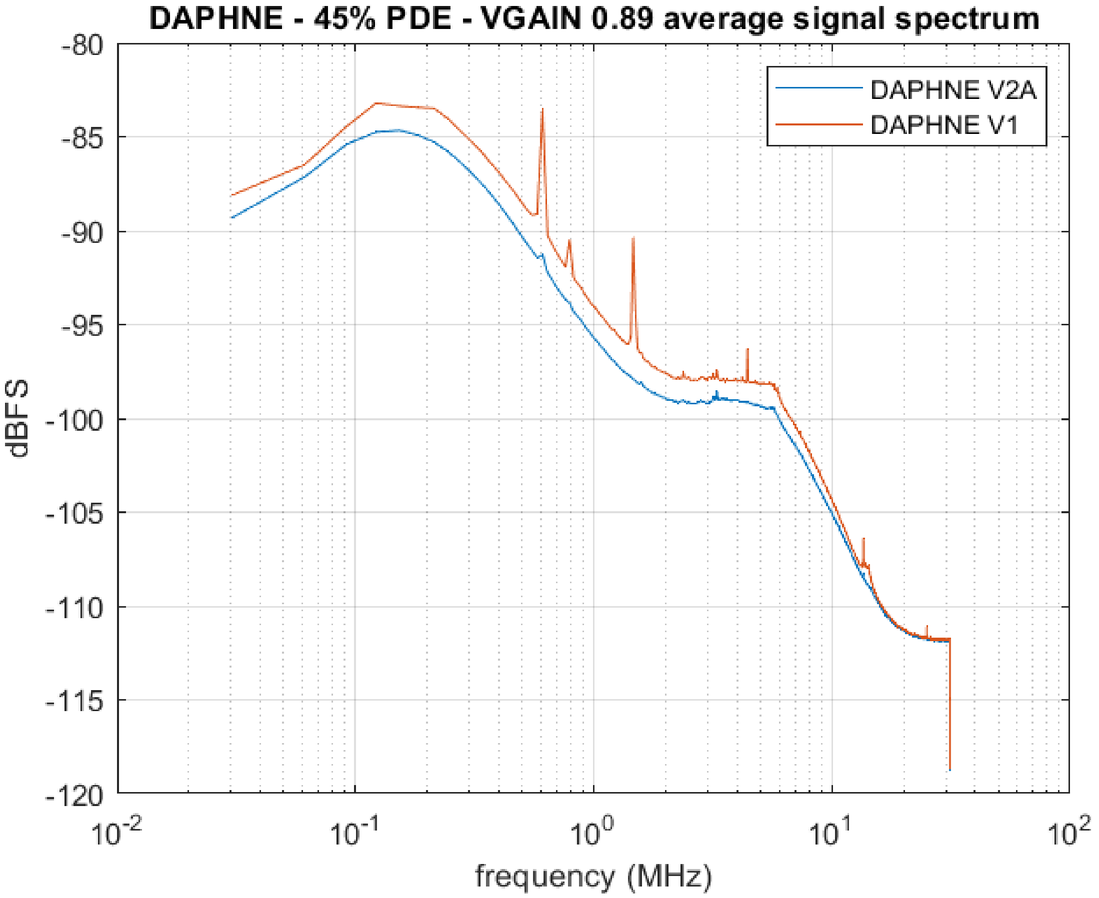
Signal Spectrum Comparison – FBK

Integrators OFF

40% PDE



45% PDE

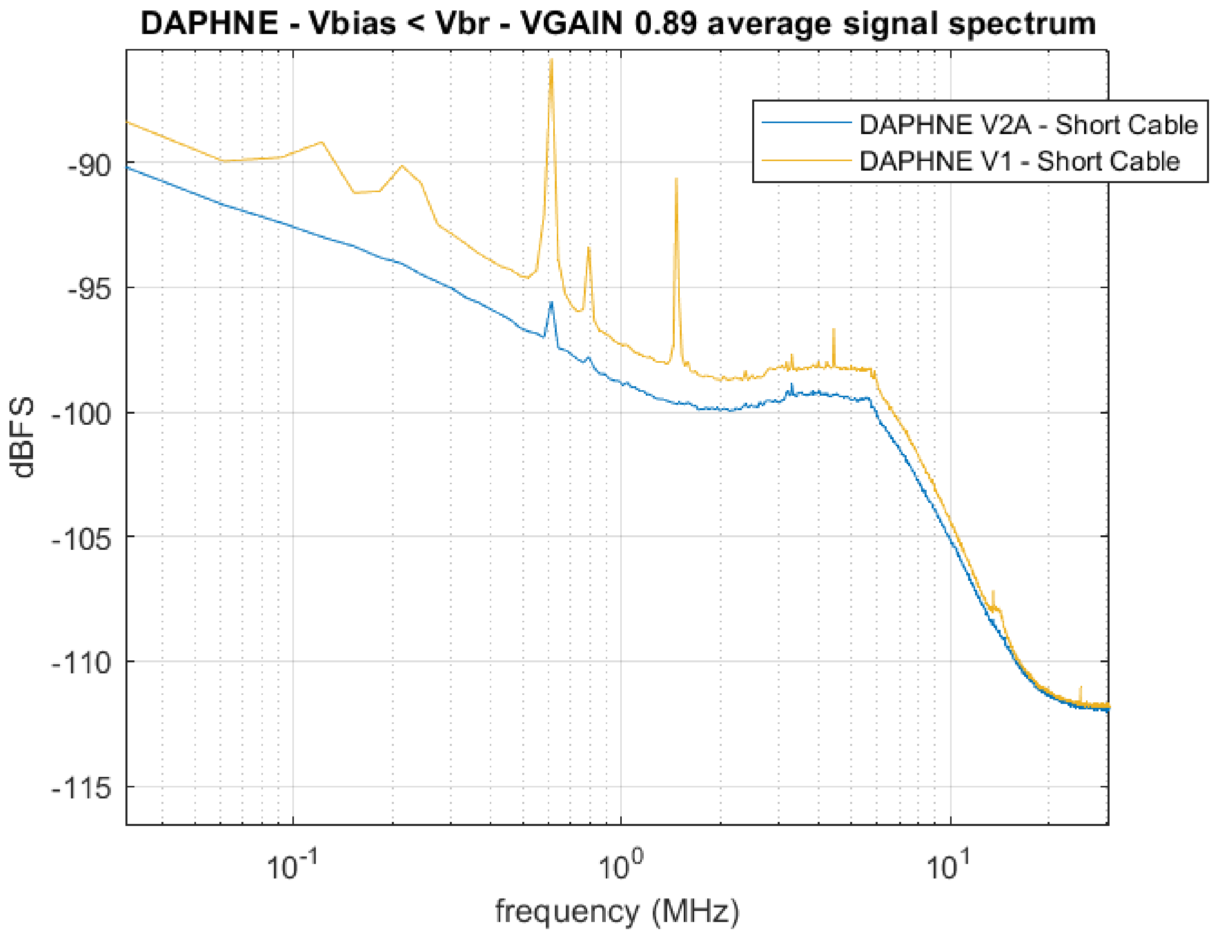


Signal Spectrum Comparison – FBK

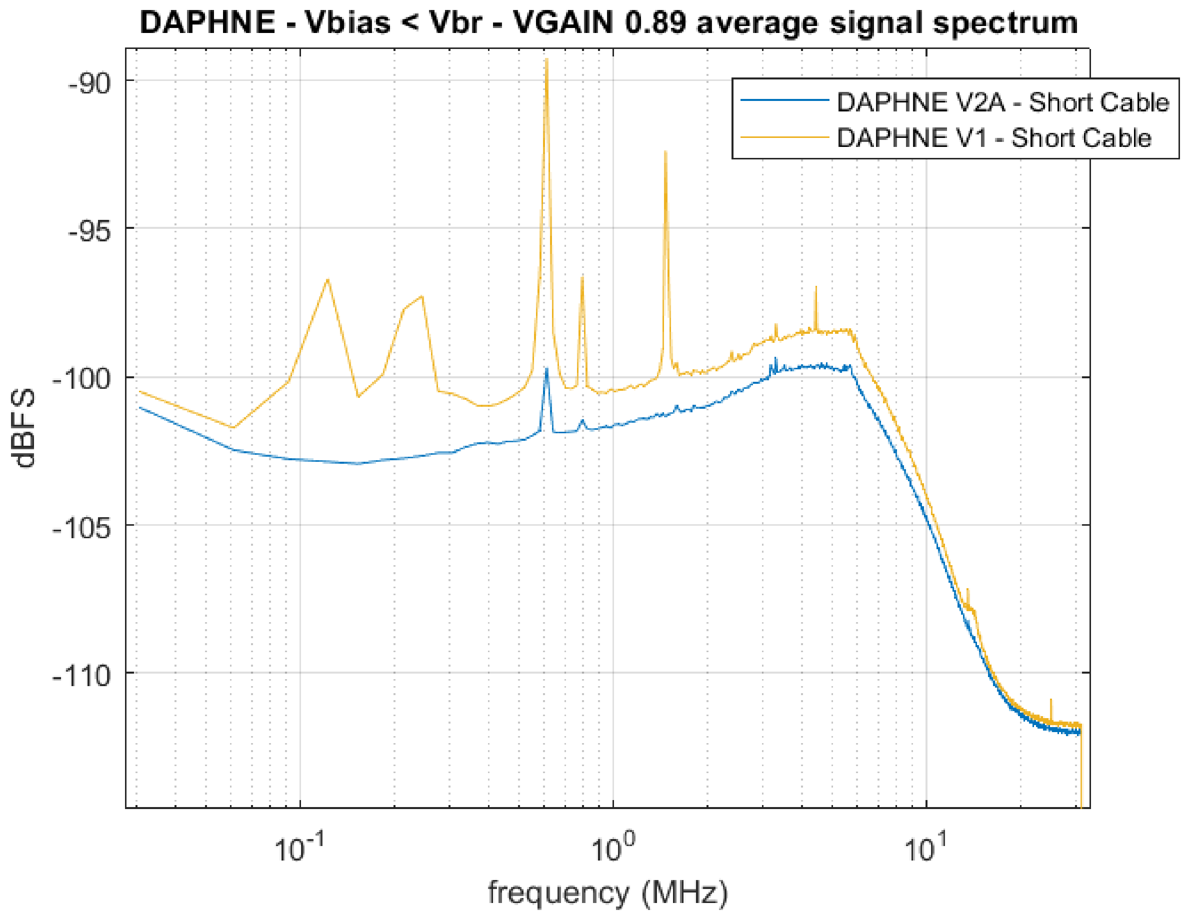
$V_{bias} < V_{br}$ *

Short Cable – 2m

Integrator OFF



Integrator ON



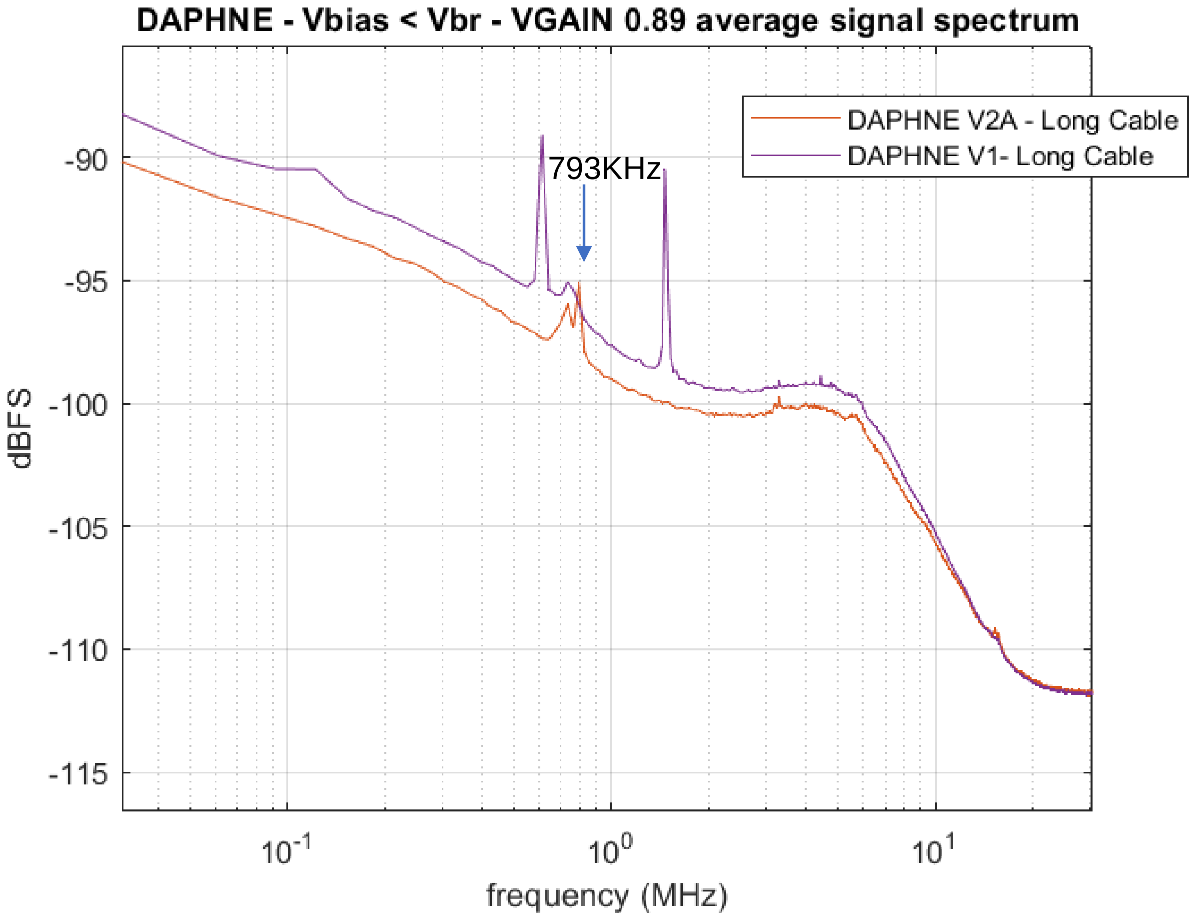
* V_{bias} is set 0.5V below the breakdown voltage V_{br}

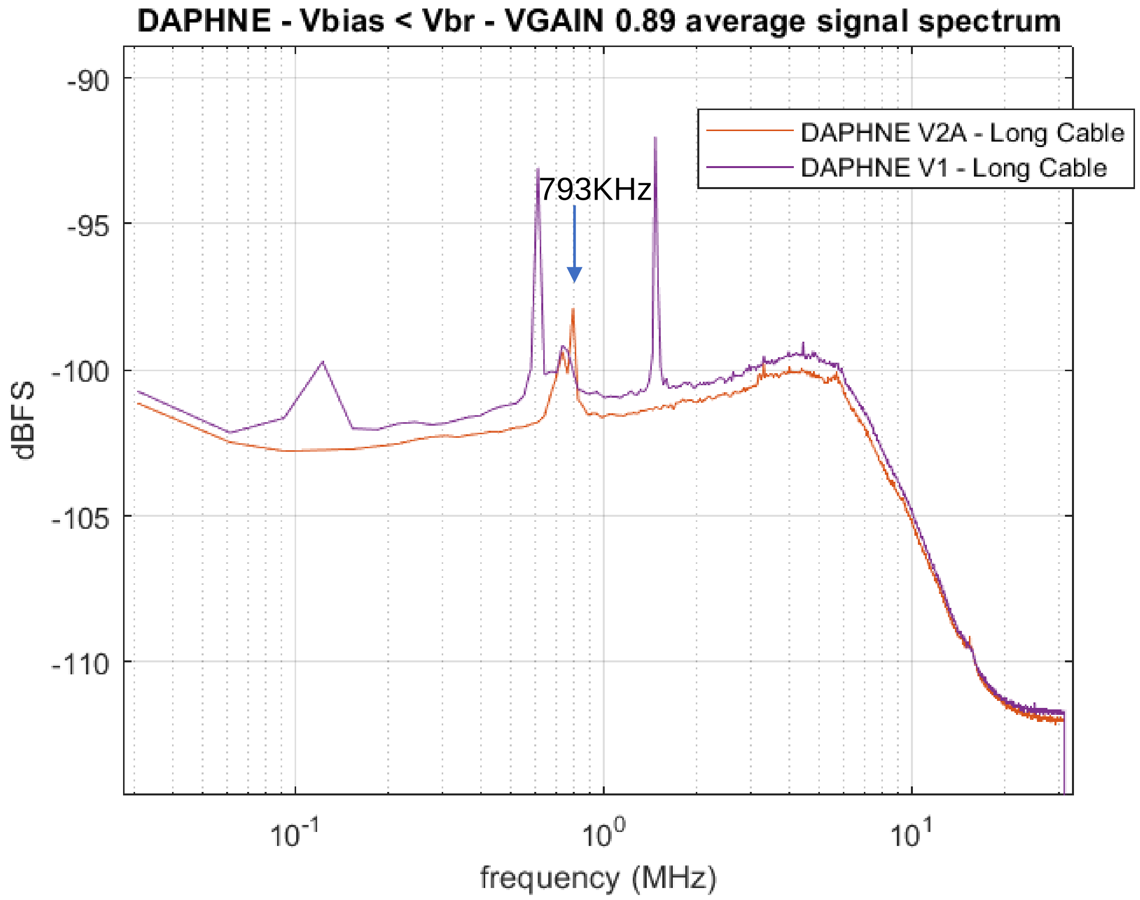
Signal Spectrum Comparison – FBK

Integrator OFF

Long Cable – 30m

Integrator ON





DAPHNE GROUNDING

DAPHNE GROUNDING

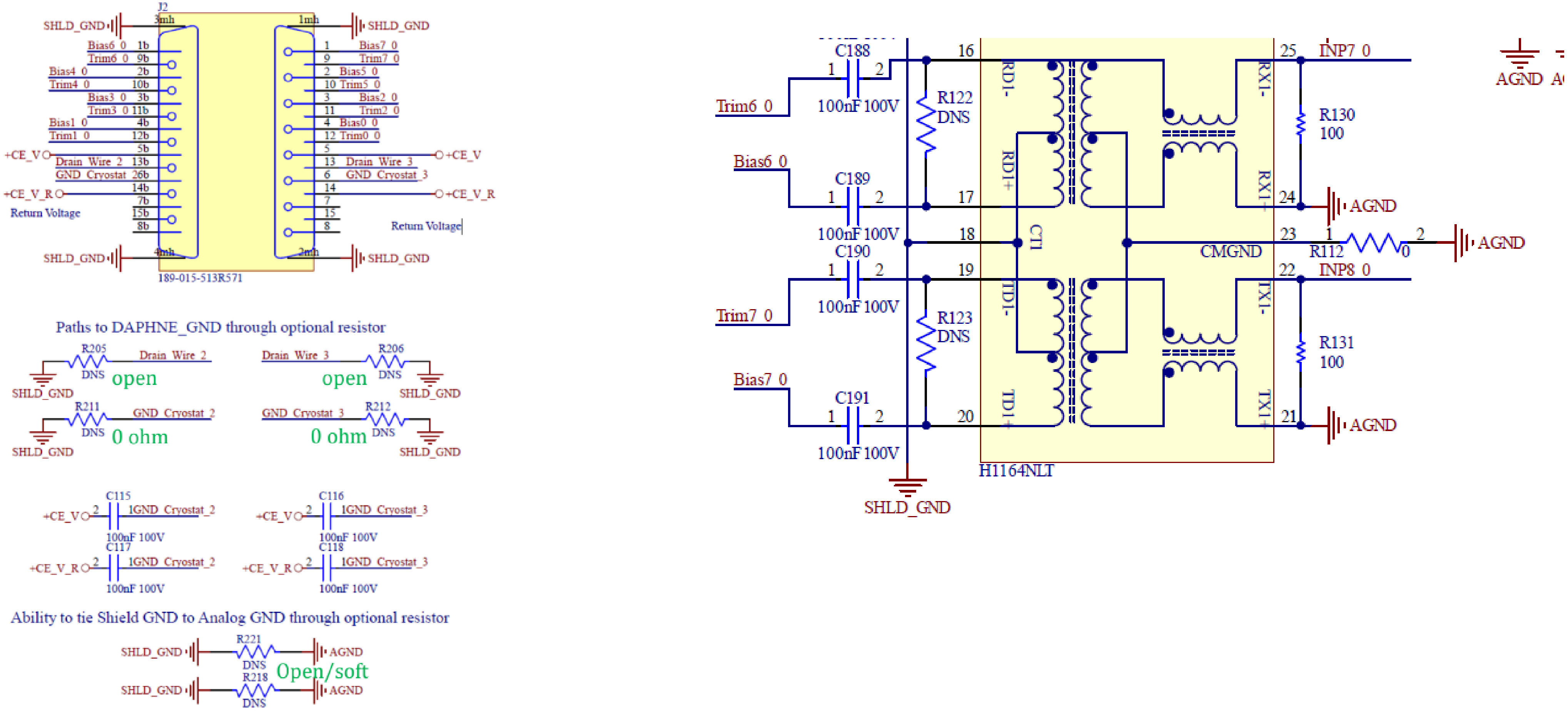
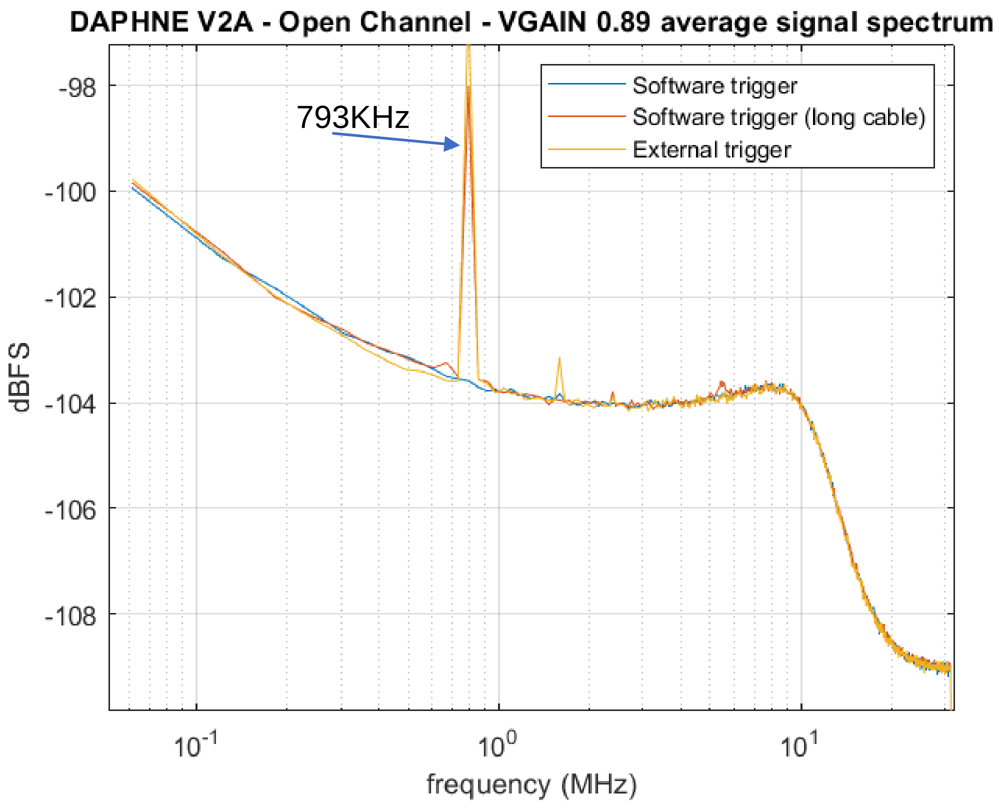
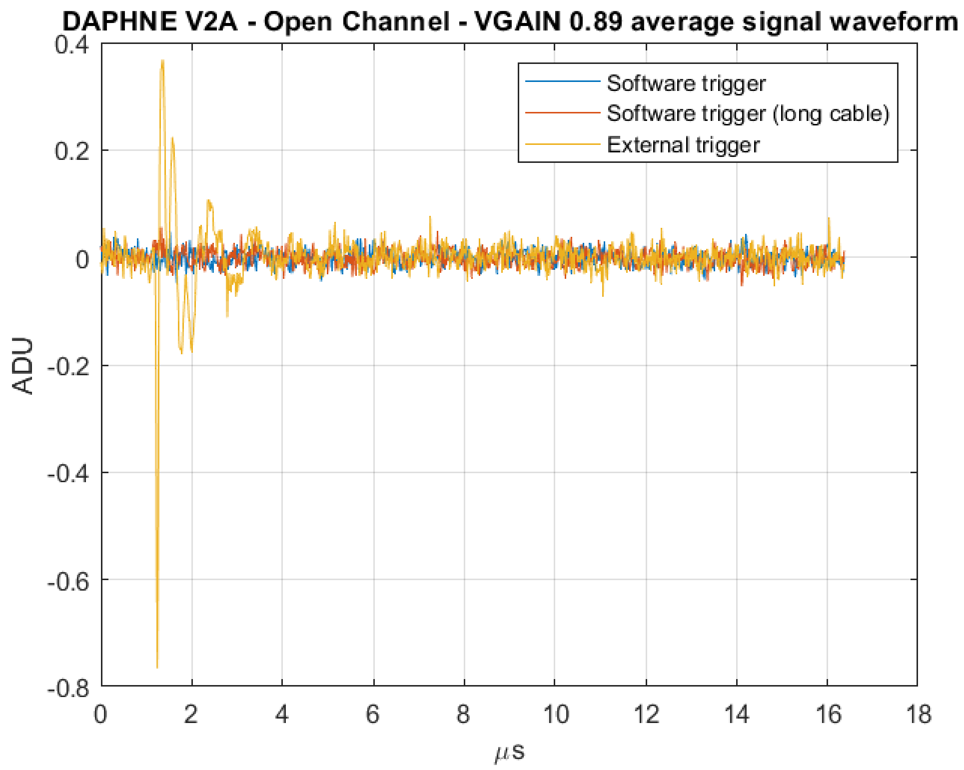


Figure 10 – Extract of the DAPHNE schematic showing the implementation of the grounding diagram. Connector J2 serves two PD modules (2x 15-pin D-sub connectors). The suggested values are written in green.

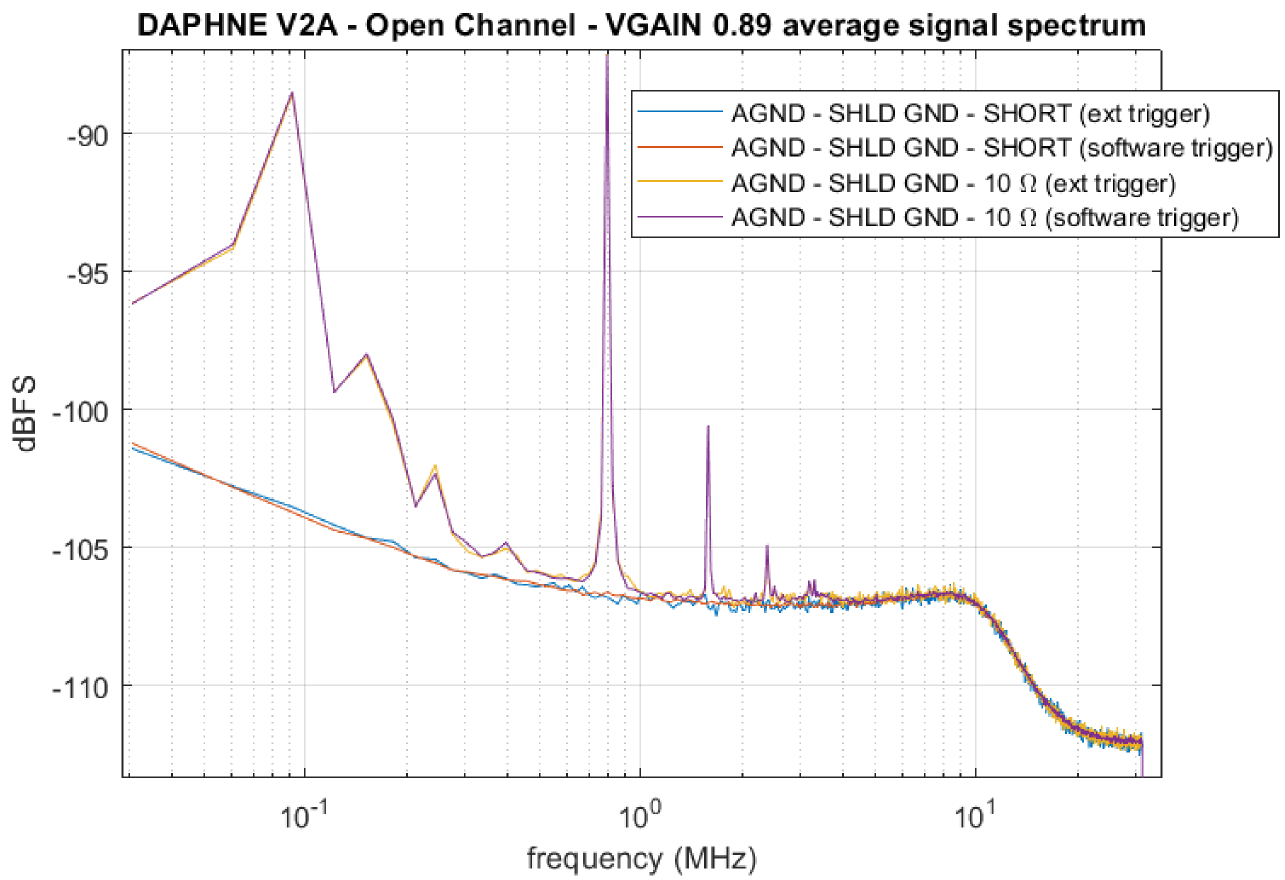
GROUNDING – ALL GND OPENED





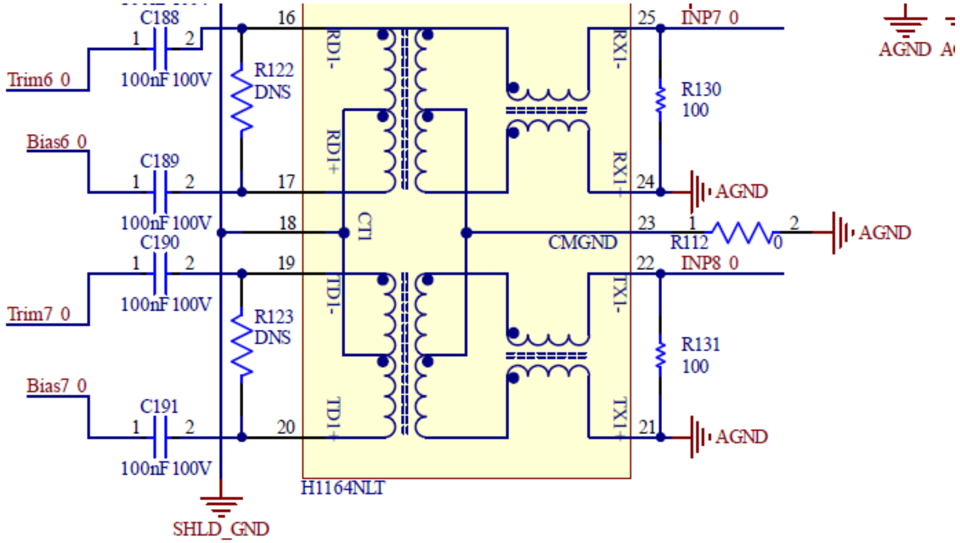
- With all GND disconnected, performing a software trigger and capturing waveforms yields a very clean noise spectrum.
- When DAPHNE is connected in any way to an external device (long cable at the input or the waveform generator to issue the trigger signal), we see a spike (793KHz) resonance.
- The external trigger rising edge (and falling) signal is coupled into the waveform, causing a dampened oscillation at the trigger point (and falling edge point).

AGND – SHLDGND soft/0ohms CONNECTION



- With DAPHNE V2A channels open, the figure in the left shows the noise spectrum when a soft 10Ω connection is set between AGND and SHLDGND versus a shorted 0Ω connection.
- The shorted 0Ω connection has a very clean noise spectrum for software trigger and external trigger conditions (no dampened oscillations is observed).
- The shorted 10Ω connection causes an immediate resonance seen for both software an external trigger, where 793KHz is one of the harmonics.

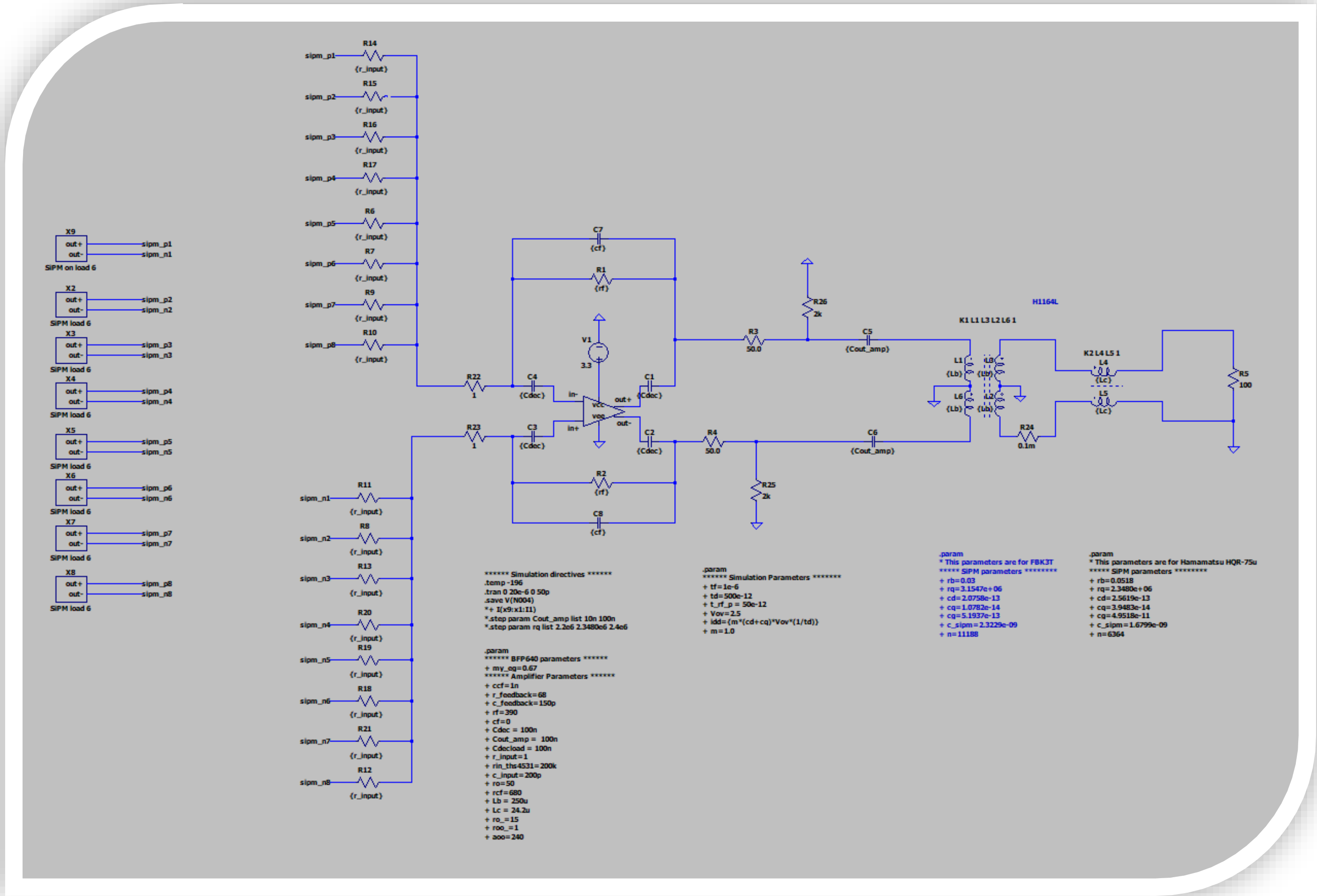
DAPHNE GROUNDING

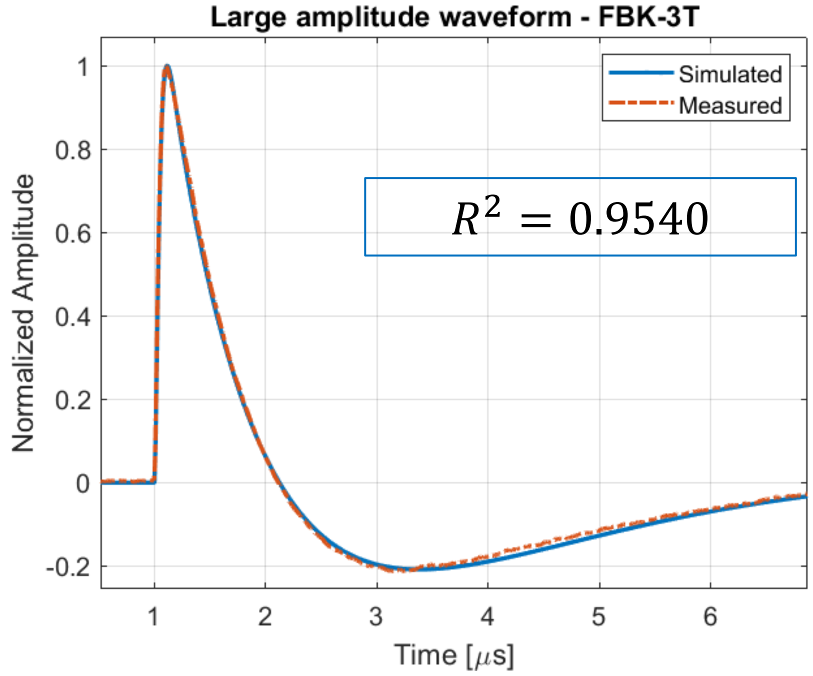


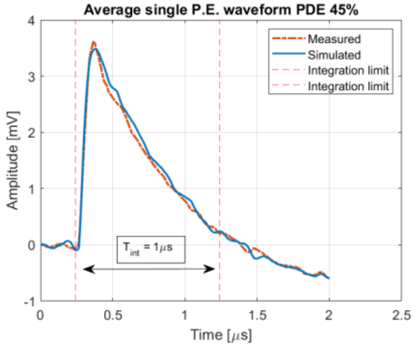
- SHLD_GND and AGND are completely isolated (as it's should). But there is an issue with the center tap in the primary which will be floating with respect of AGND.
- Ideally, no current flows through the center tap in the primary, assuming a perfectly balanced signal, perfect coupling between primary and secondary.
- Also, imperfect coupling in the choke and capacitive coupling between the primary and secondary must be taken into account.
- We measured a ~300mV voltage difference between AGND and the center tap, any AC component then could be leaking into the AFE input.
- Therefore, a way to reference the center tap must be found (this does not mean a connection between SHLD_GND and AGND).

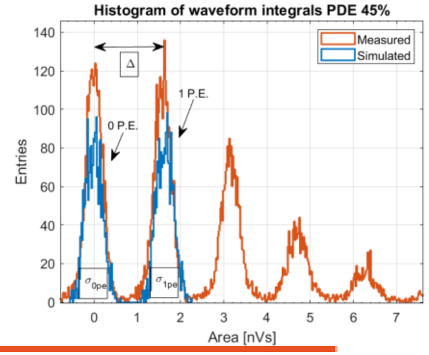
Undershoot mitigation

Undershoot mitigation – SPICE SIMULATION

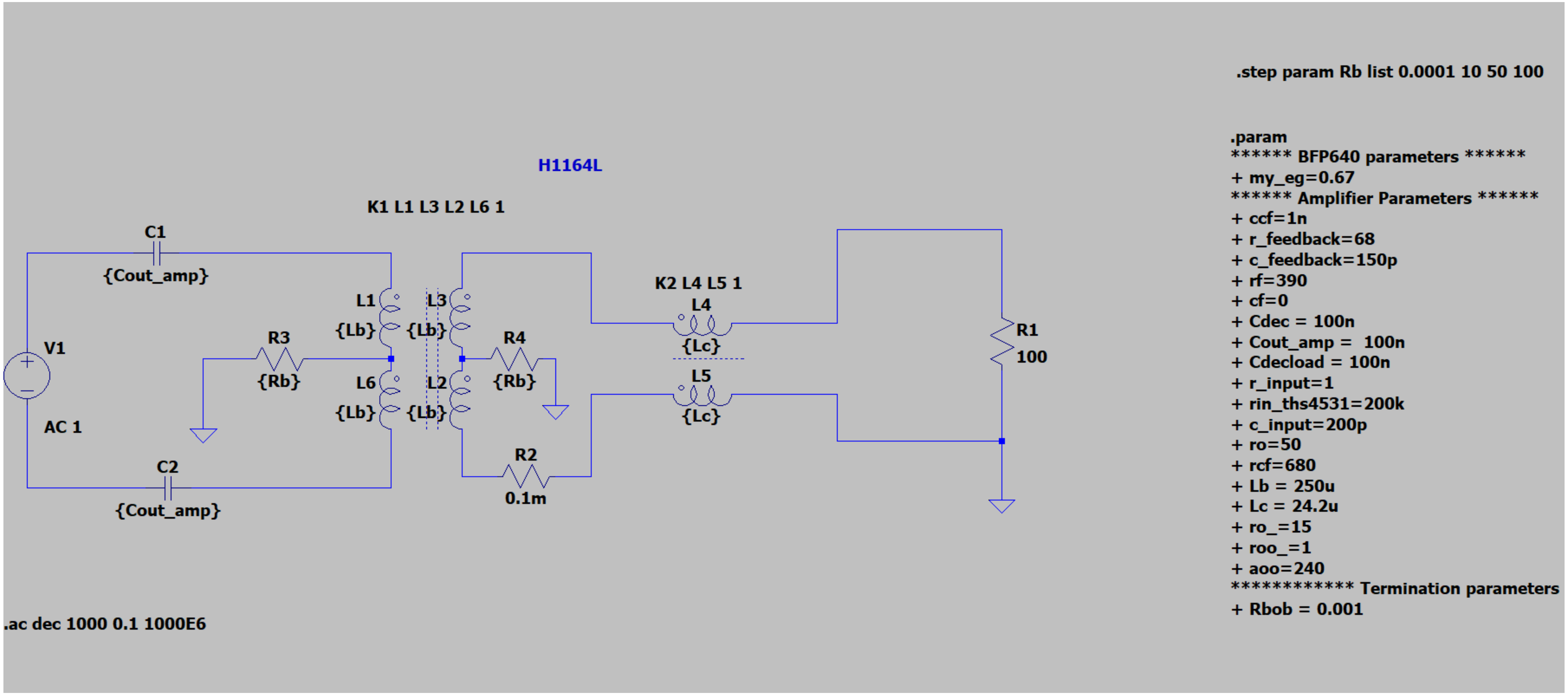








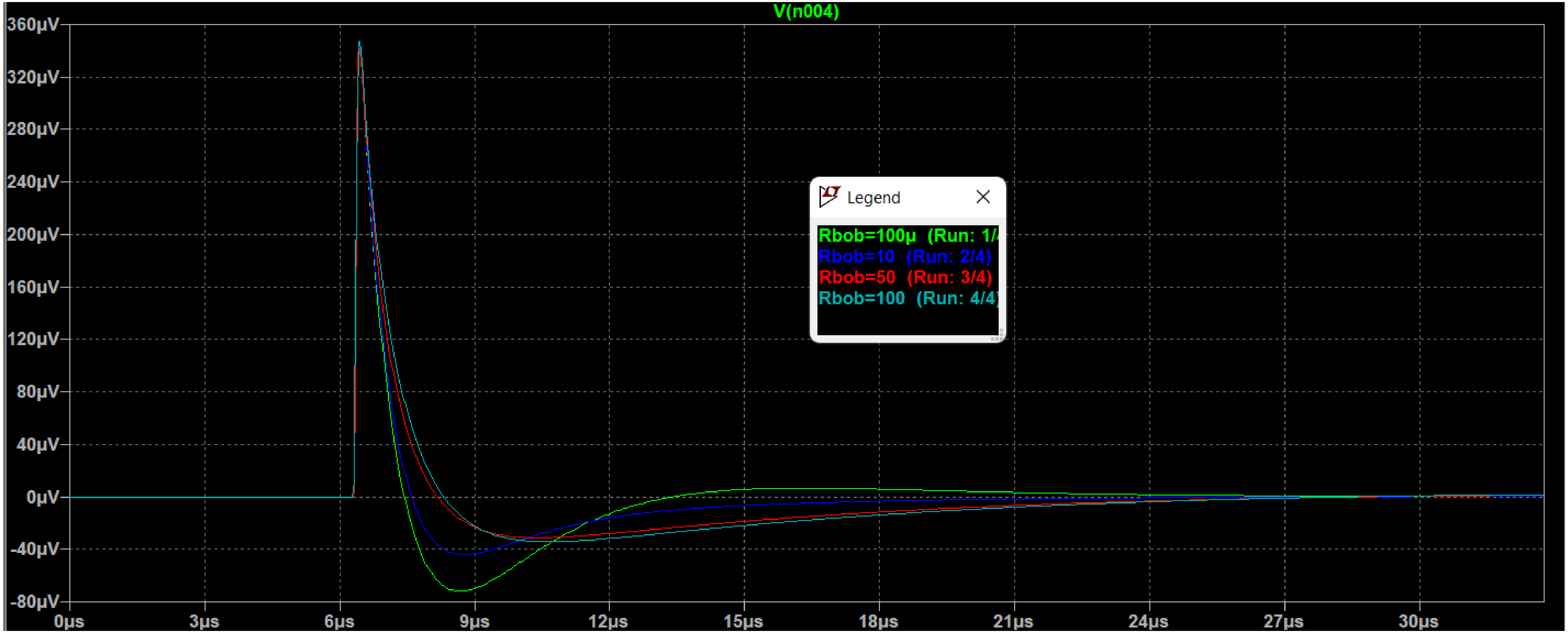
Undershoot mitigation – Input impedance



Undershoot mitigation – Input impedance

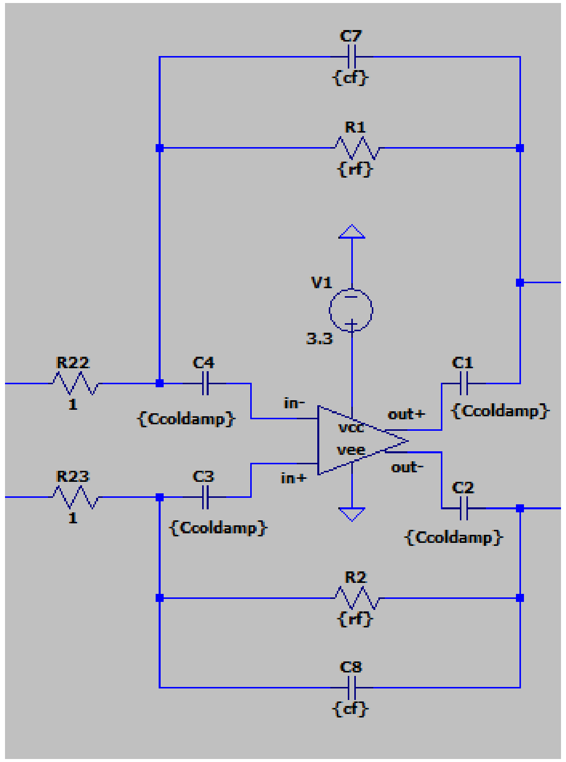
- At around 80KHz, we have a valley in the input impedance value, causing a mismatch at those frequencies. This mismatch in term causes those components to be seen with larger amplitude at the AFE input.

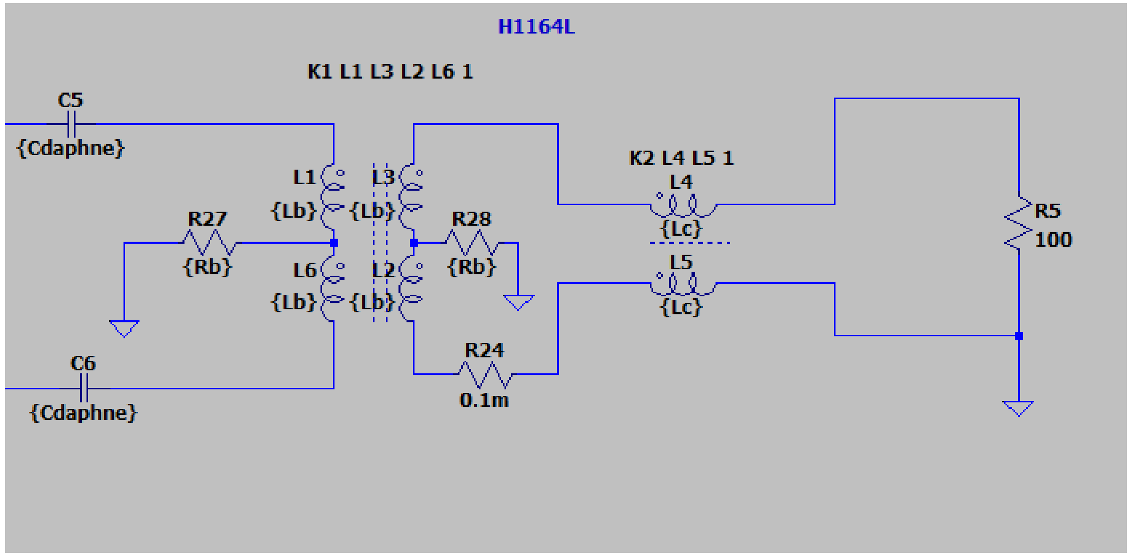
Undershoot vs R_b



- Increasing the value of R_b decreases the undershoot but increases the recover time of the signal.

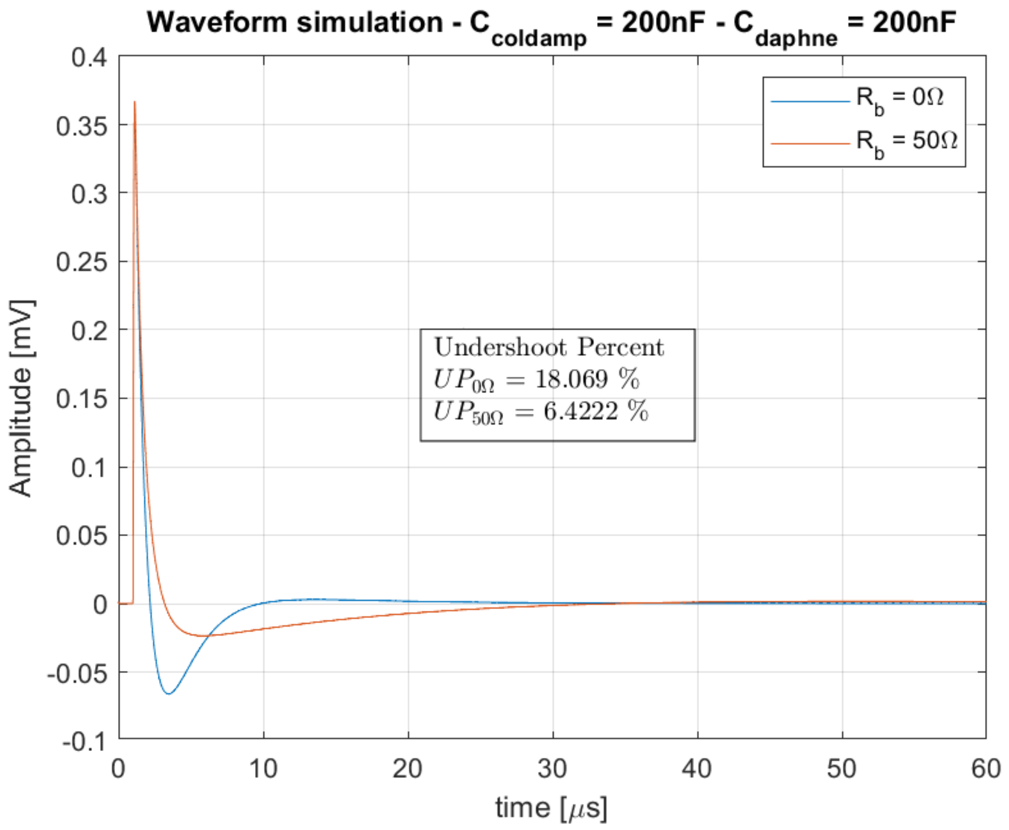
Parameters $C_{coldamp}, C_{daphne}$ and R_b

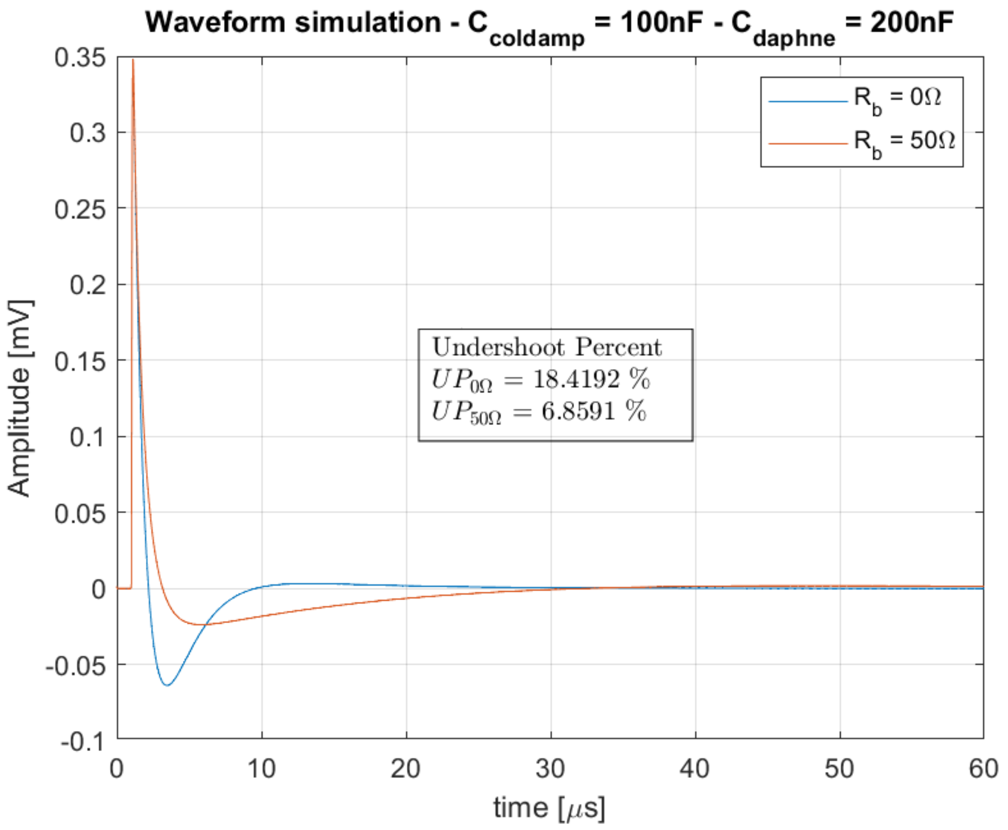




- $C_{coldamp}$ is the capacitor that decouples the bias and trim voltages in the cold amplifier's feedback loop. Operates at cold.
- C_{daphne} capacitor that decouples the bias and trim voltages from the transformer primary.
- R_b is the termination resistor connecte at the center tap of the transformer's primary and secondary.

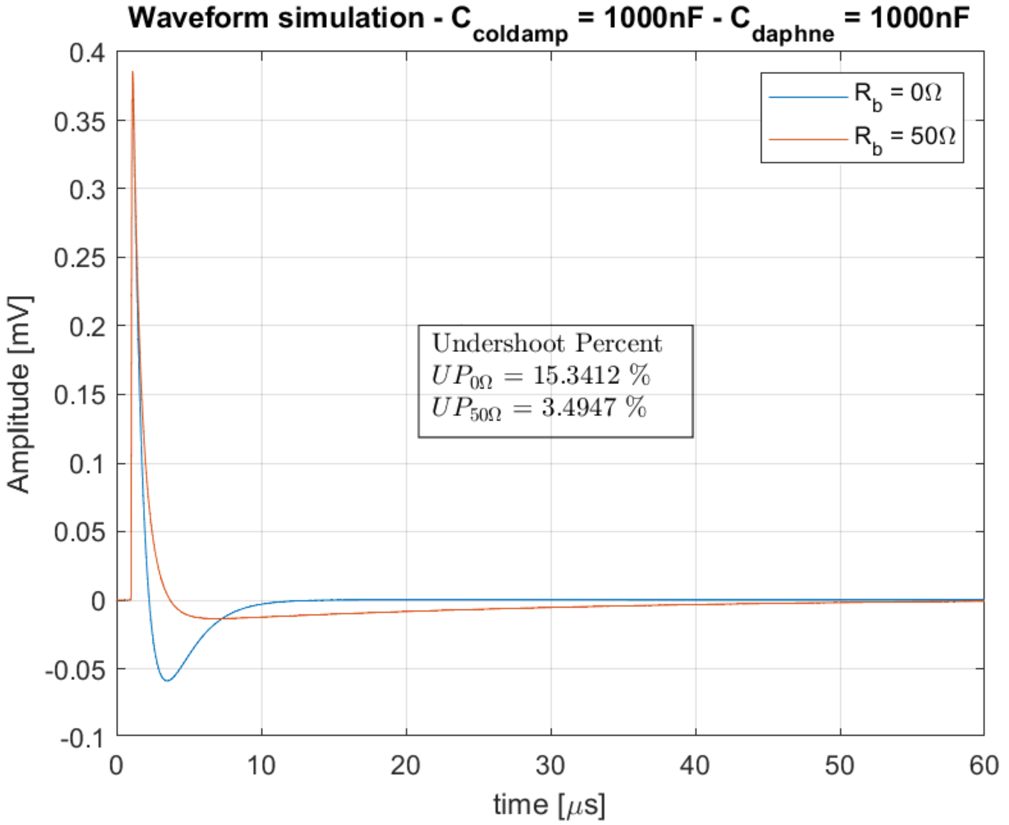
Contribution of $C_{coldamp}$

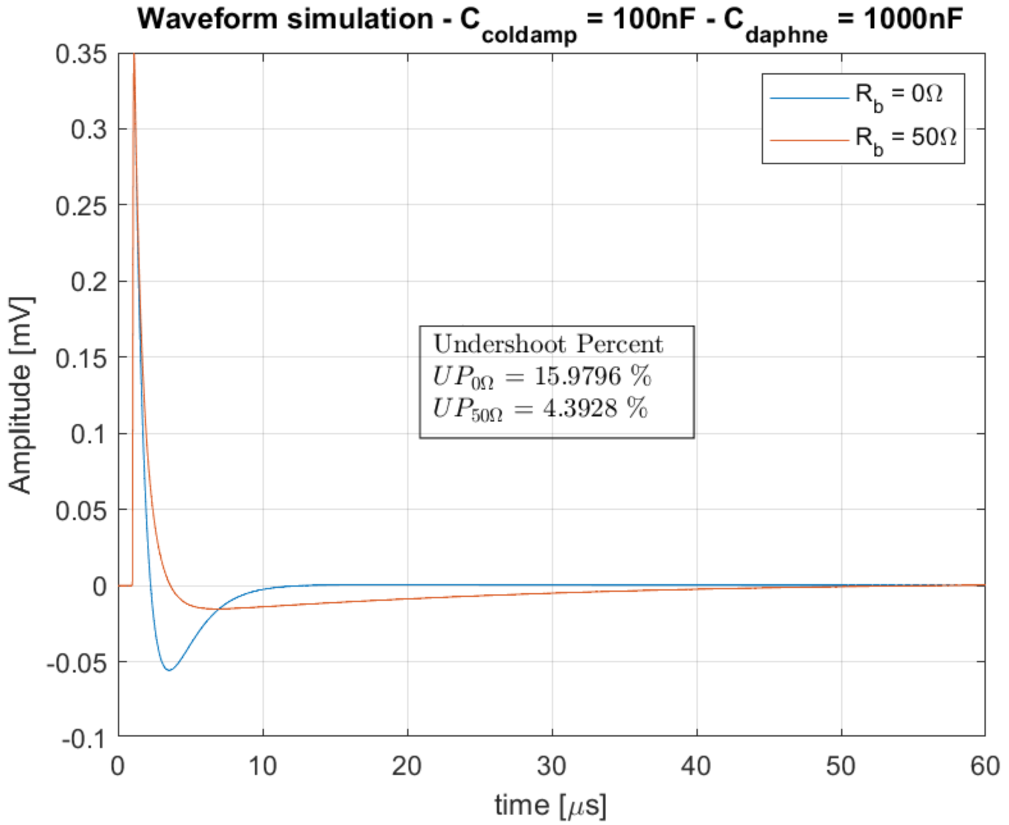




- Increasing $C_{coldamp}$ by a factor 2 yields around 0.4% improvement in undershoot.

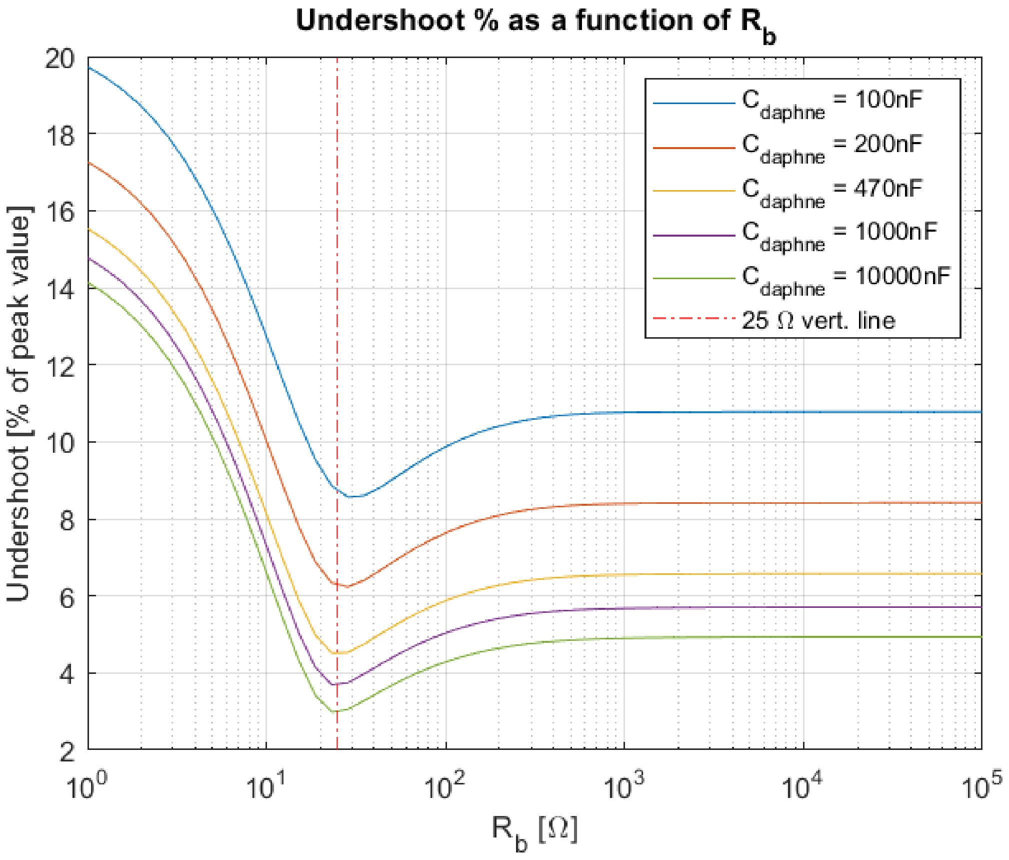
Contribution of $C_{coldamp}$

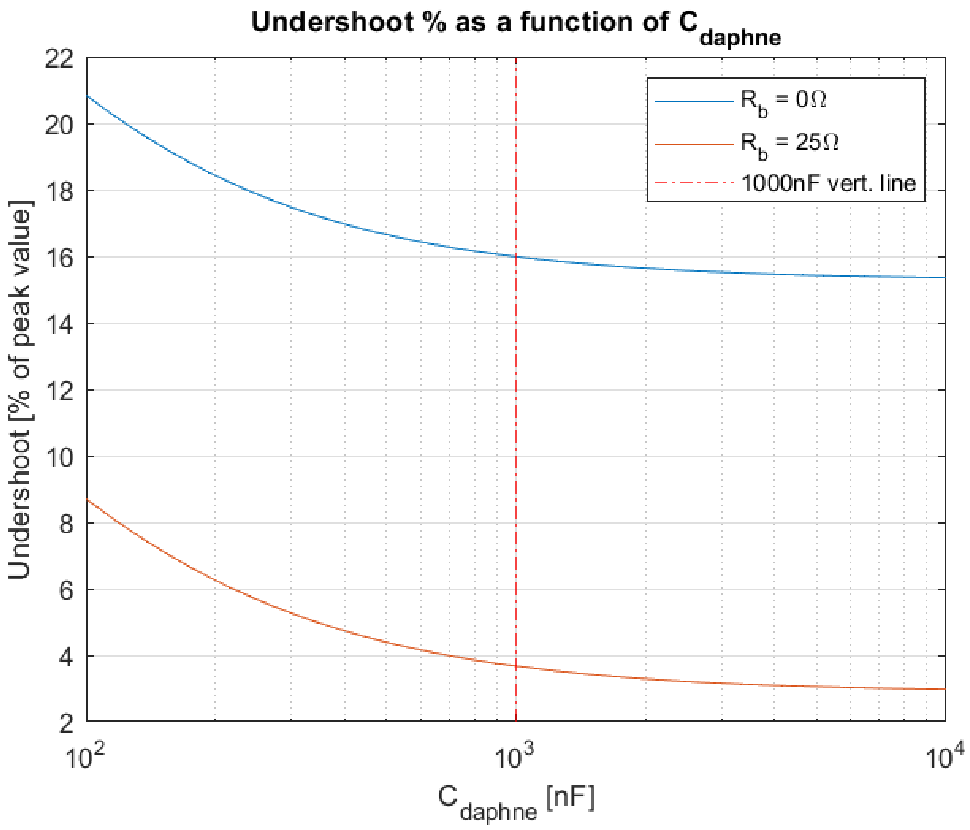




- Increasing $C_{coldamp}$ by a factor 10 yields around 0.9% improvement in undershoot.

Contribution of C_{daphne} and R_b

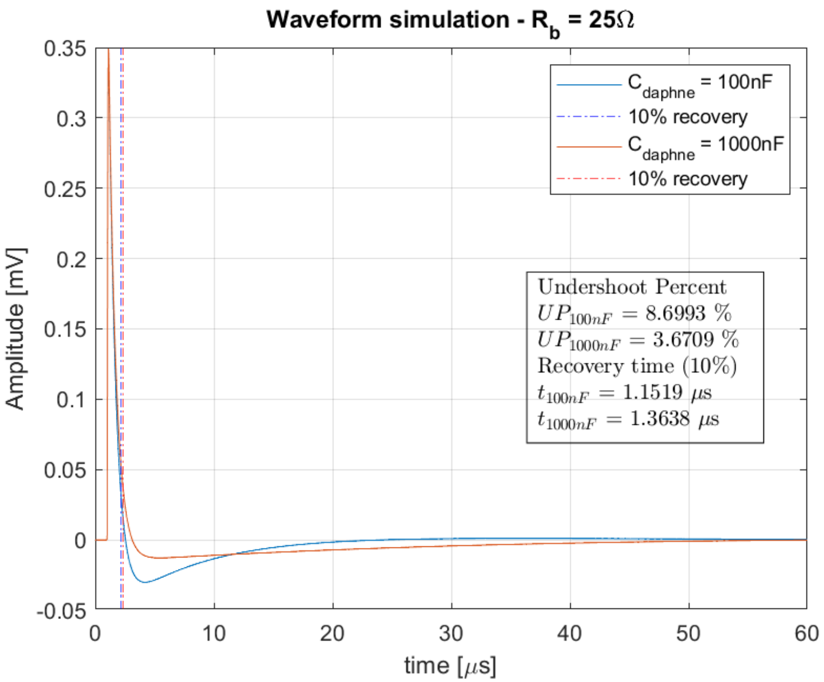




- R_b and C_{daphne} dominate the undershoot response, yielding up to around 17% reduction when $R_b = 25\Omega$ and $C_{daphne} = 1000nF$.

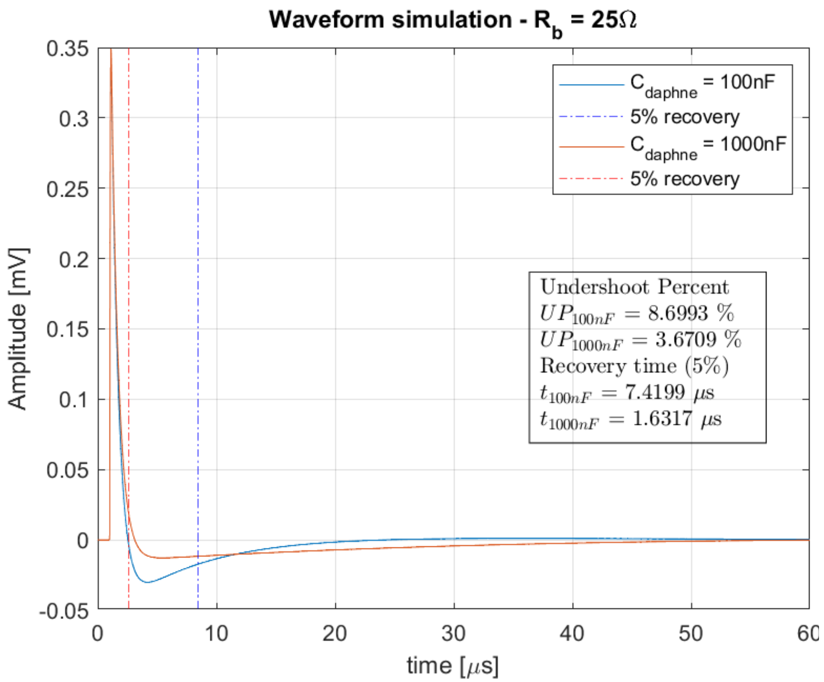
Recovery time for $R_b = 25\Omega$

10%



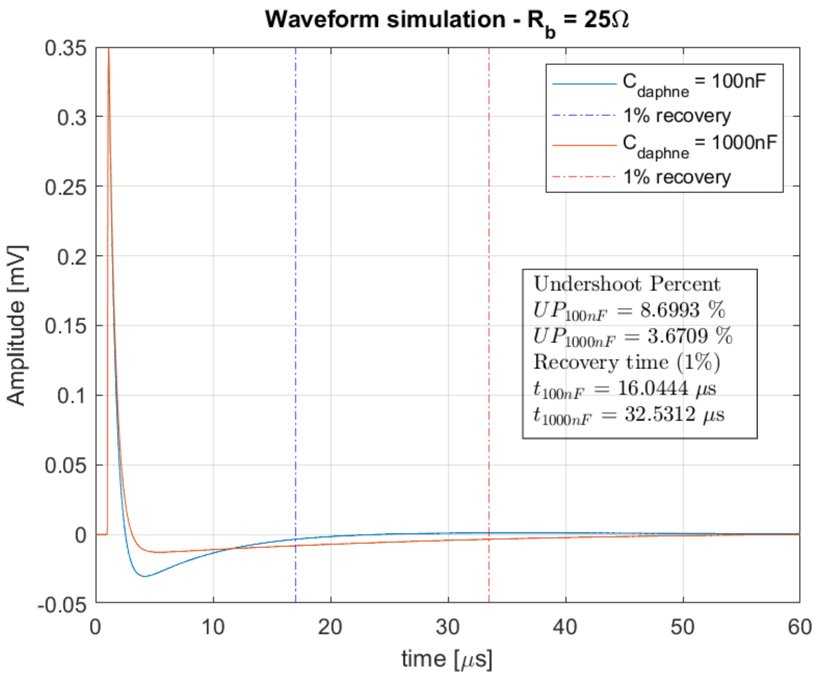
$$t_r = 1.3638\mu s$$

5%



$$t_r = 1.6317\mu s$$

1%

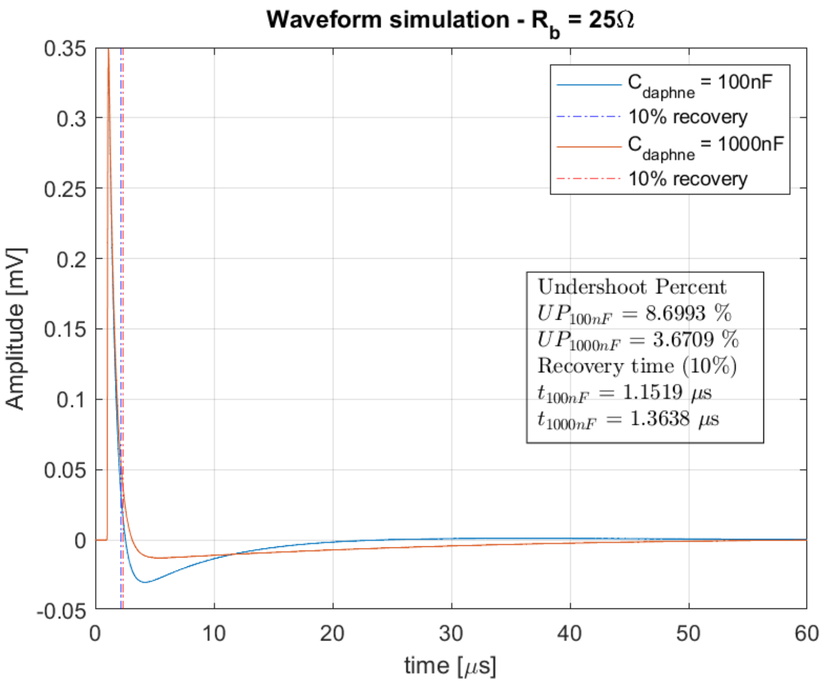


$$t_r = 32.5312\mu s$$

- The definition used for the recovery time is the time the signal takes to reach a certain % value of the peak after the impulse.

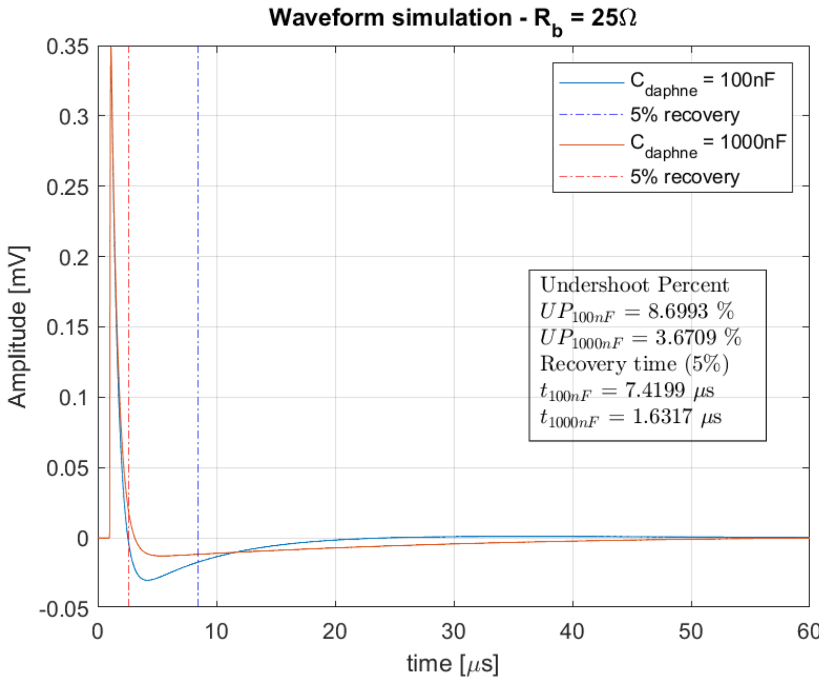
Recovery time for $R_b = 25\Omega$

10%



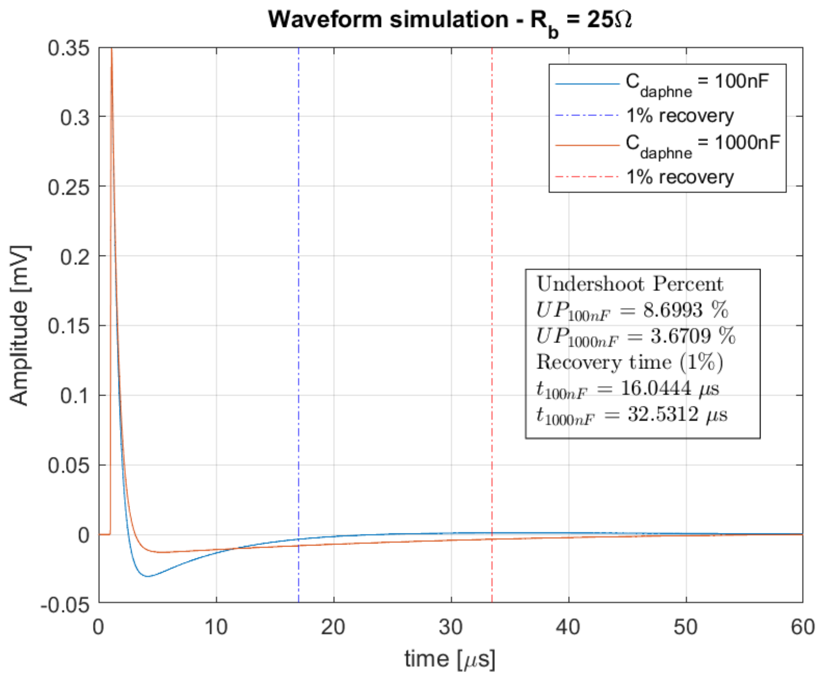
$t_r = 1.3638\mu s$

5%



$t_r = 1.6317\mu s$

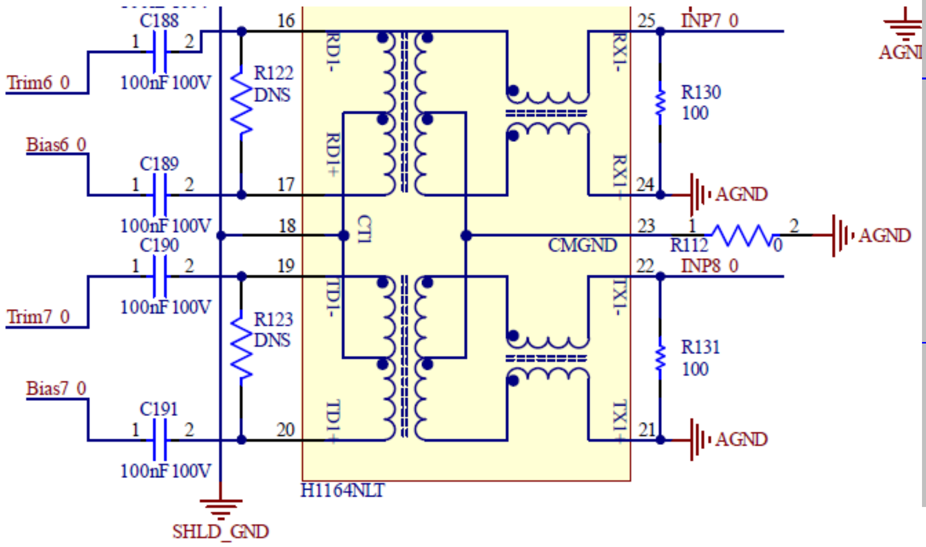
1%

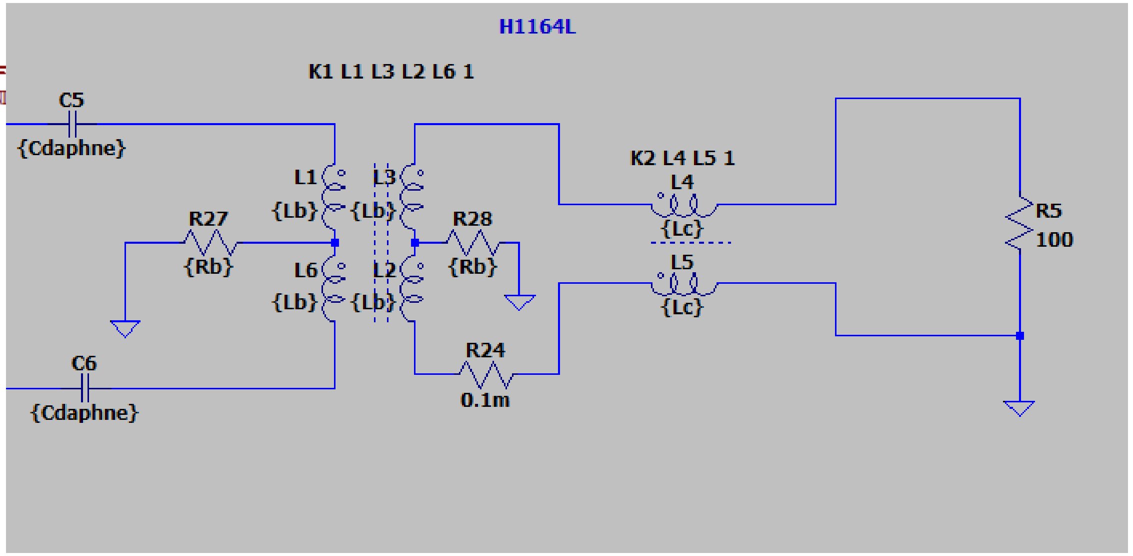


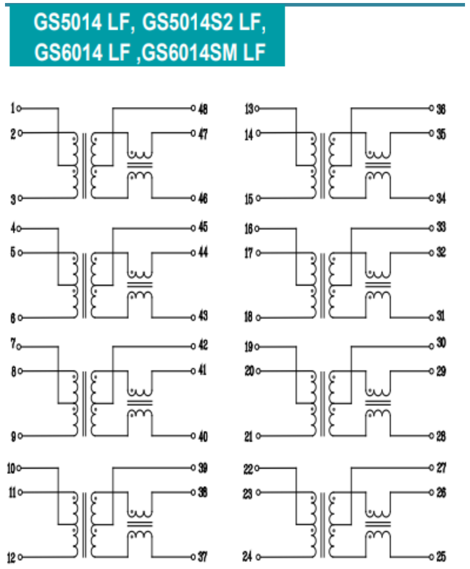
$t_r = 32.5312\mu s$

- The definition used for the recovery time is the time the signal takes to reach a certain % value of the peak after the impulse.

Recovery time for $R_b = 25\Omega$







- These changes are no easily to implement in DAPHNE V2A because the transformer H1164L shares the center tap between adyacent inputs. Changing R112 could cause signal crosstalk between channels.
- One solution is to change the trasformer H1164L for it's analogue with extra pins that has independent central taps.
- Another key aspect is that the center tap in the primary side will be referenced through $R_b = 25\Omega$ to AGND without the need to soft/short AGND and SHLD_GND.