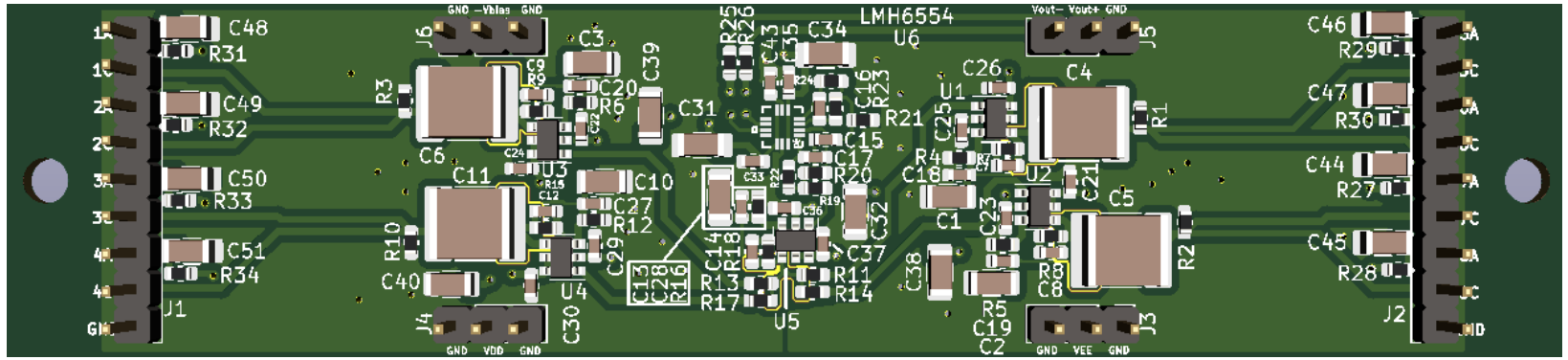
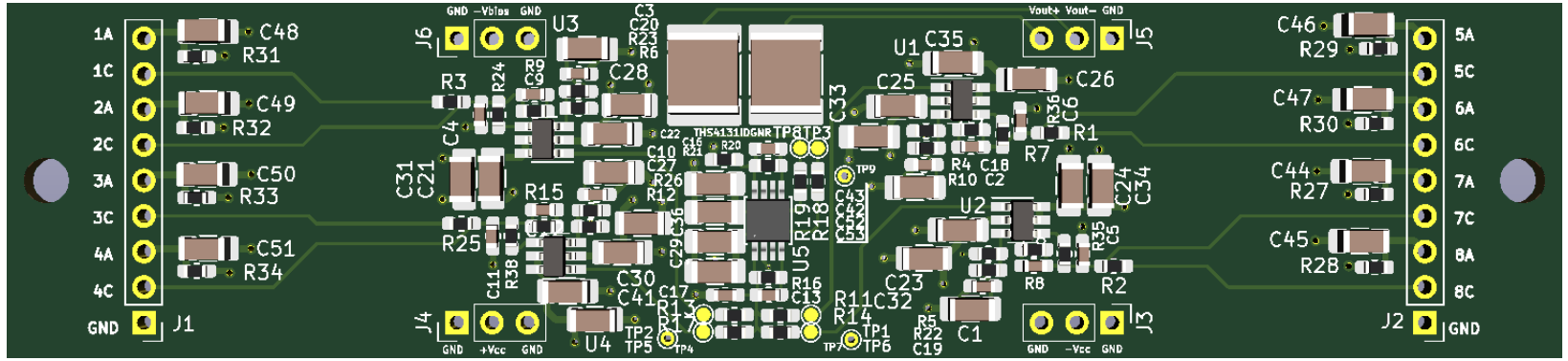
SiPM Active Ganging cryogenic test results

ING. ESTEBAN CRISTALDO

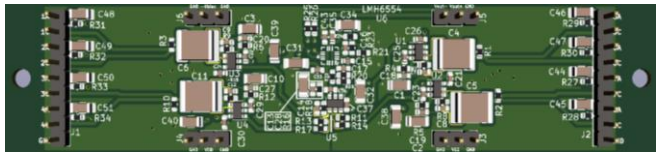
Prototype V1



Prototype V2

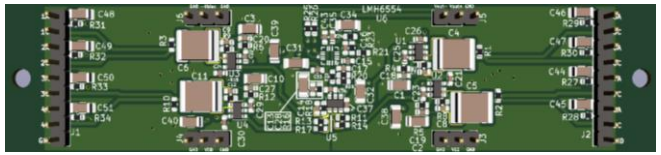


Prototype V1



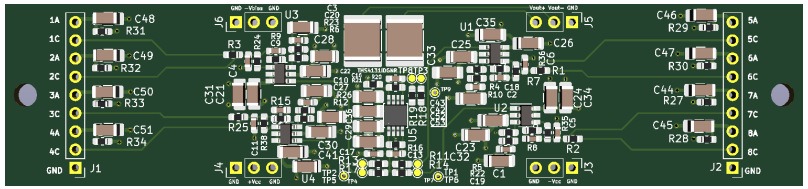
- Three stage amplifier.
- First stage consist in 4 transimpedance amplifiers, each amplifying groups of 12 SiPM’s
- Second stage is a single ended summing amplifier.
- Third stage is a Differential Low Pass Filter in multiple feedback configuration. It provides single ended to differential conversion.
- LMH6629 was used for single ended amplification and LMH6554 for differential amplification.

Prototype V1 test summary



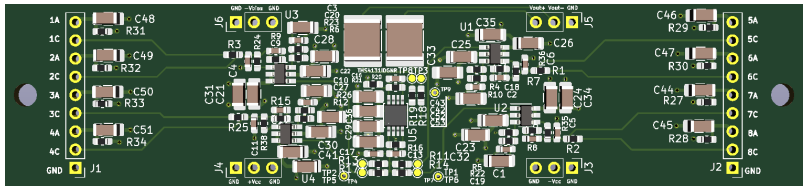
- Prototype V1 did not meet operation conditions due to high instability of the single ended stages (LMH6629).
- LMH6554 introduces distortion in the signal when operating as Low Pass Filter. Voltage inverter configuration was tested but distortion was still present in high amplitude signals.
- Stable operation was achieved when stages were separately tested, but once connected oscillatory condition appeared.

Prototype V2



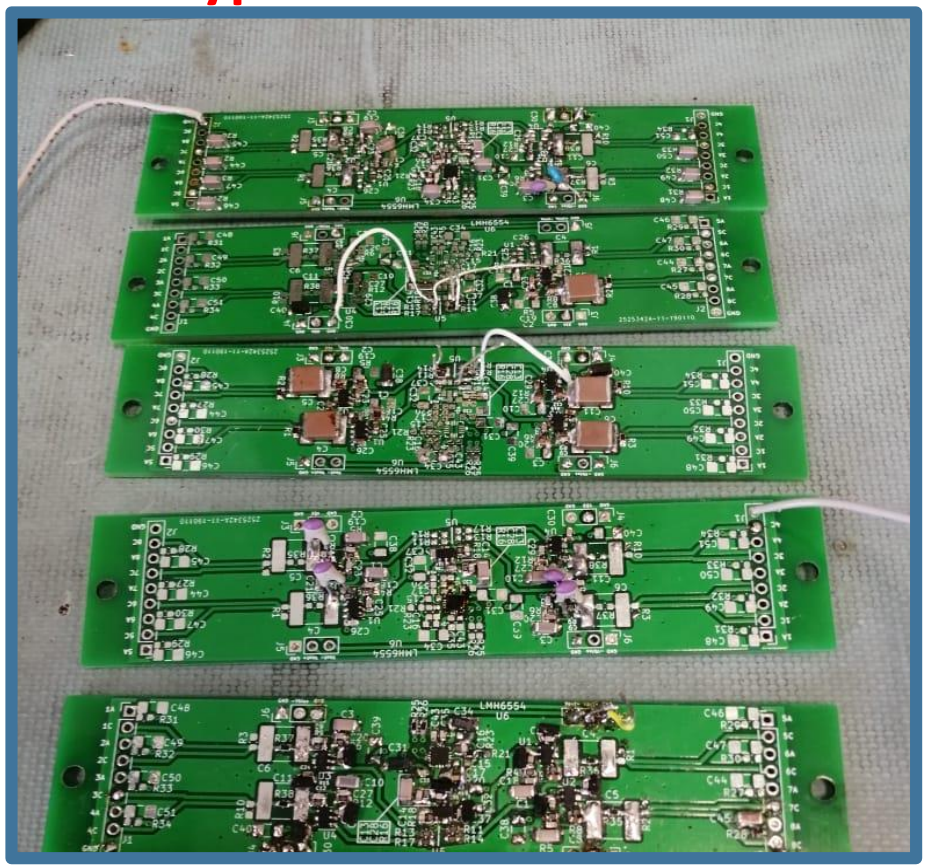
- Two stage amplifier.
- First stage consist in 4 transimpedance amplifiers, each amplifying groups of 12 SiPM’s
- Second stage of prototype V2 replaced second and third stage of protype V1, providing summing mode and single ended to differential conversion.
- OPA847 replaced LMH6629 and THS4131 replaced LMH6554.

Prototype V2 test summary



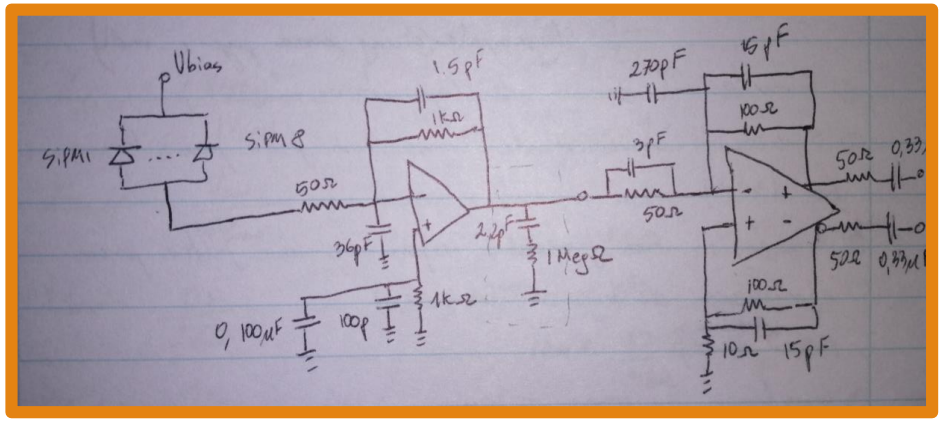
- Prototype V2 meet operation conditions at room and cryogenic temperatures.
- Distortion in the signal was not present, even with large signals.
- Low amplitude, high frequency oscillatory condition was present. This was mitigated adding compensation networks in between stages.
- 1 MPPC and 8 MPPC in parallel were tested due to availability of the SiPM’s sensors.

Prototype V1

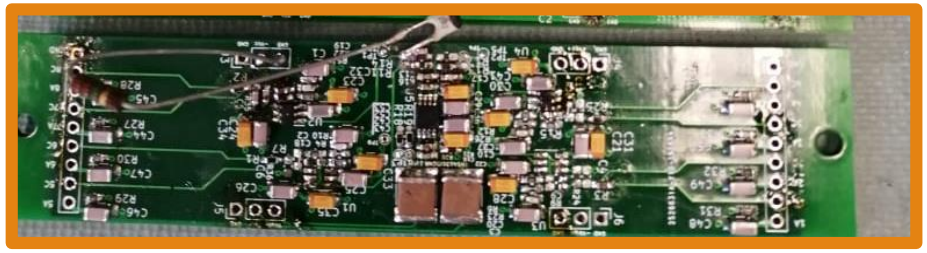


Prototype V1 was thoroughly tested, but obtaining a satisfactory operation condition was in vane.

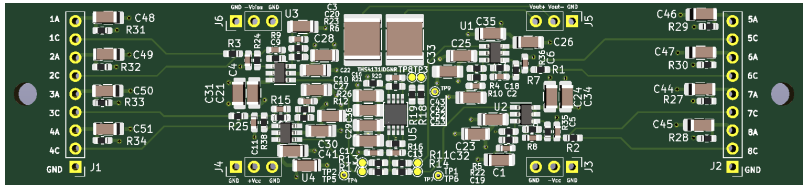
Prototype V2 achieved satisfactory operation condition.

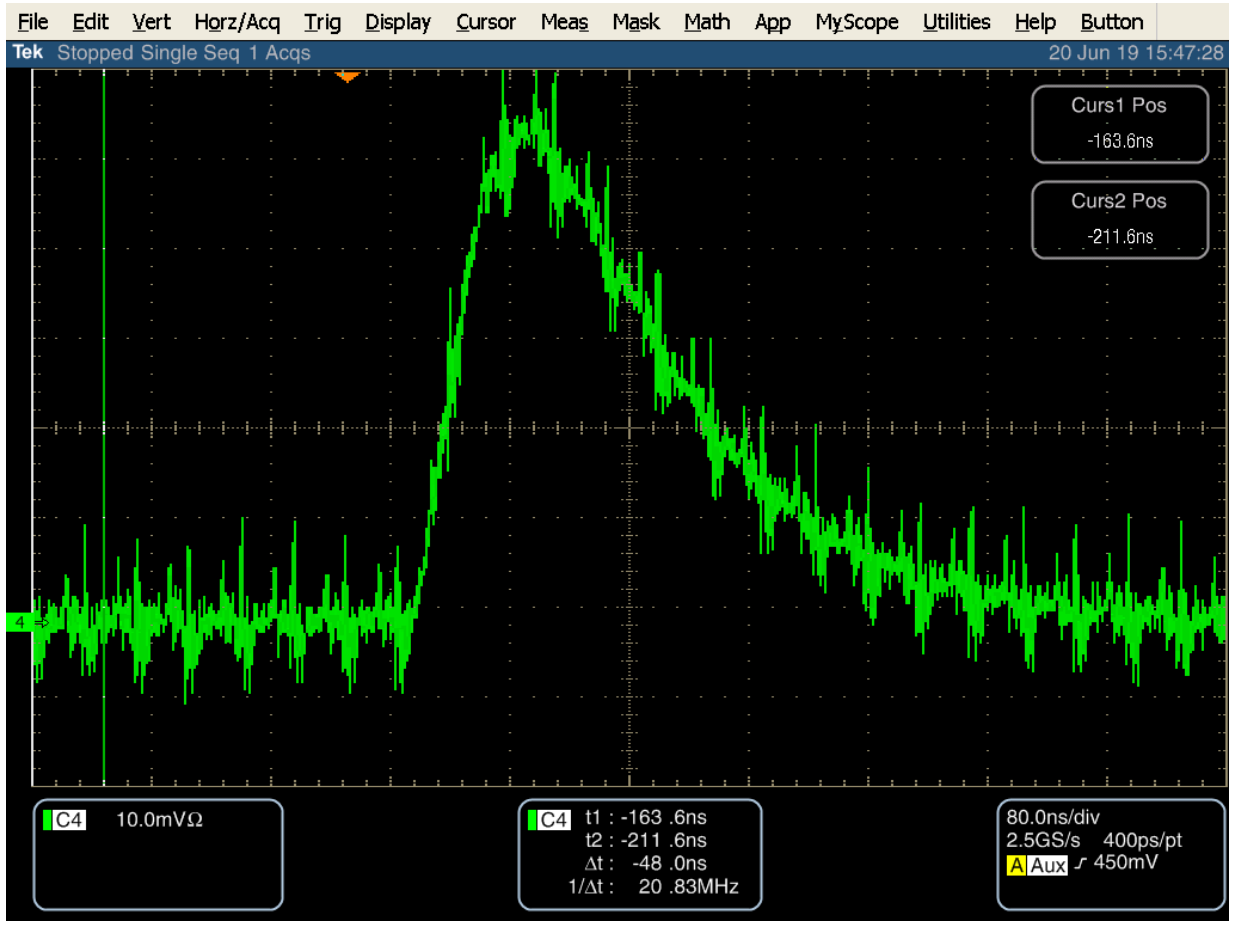


Prototype V2



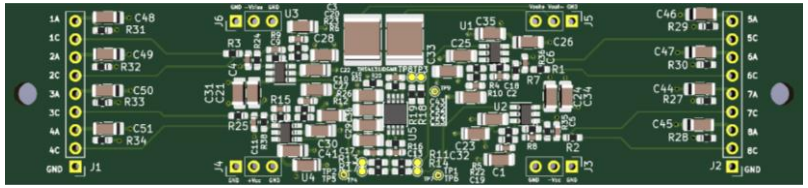
Prototype V2 test @ room temperature

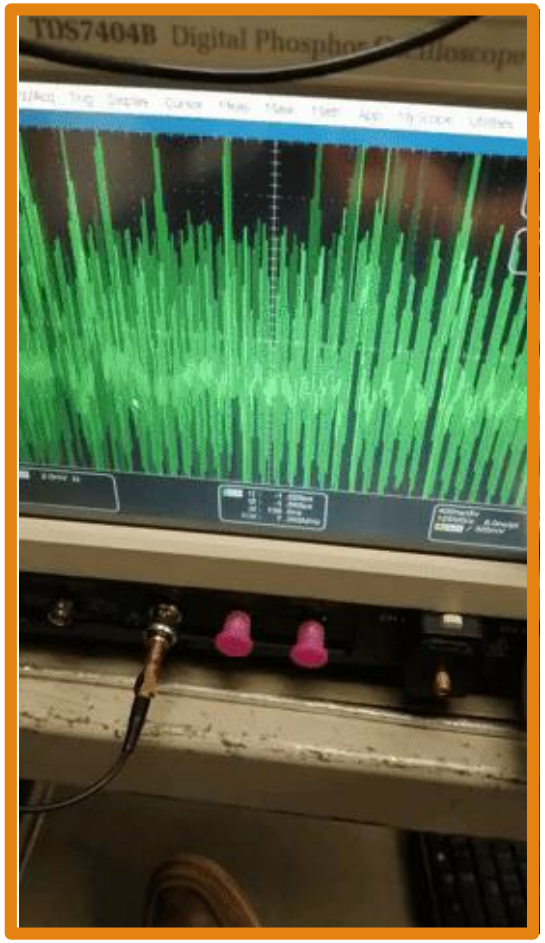




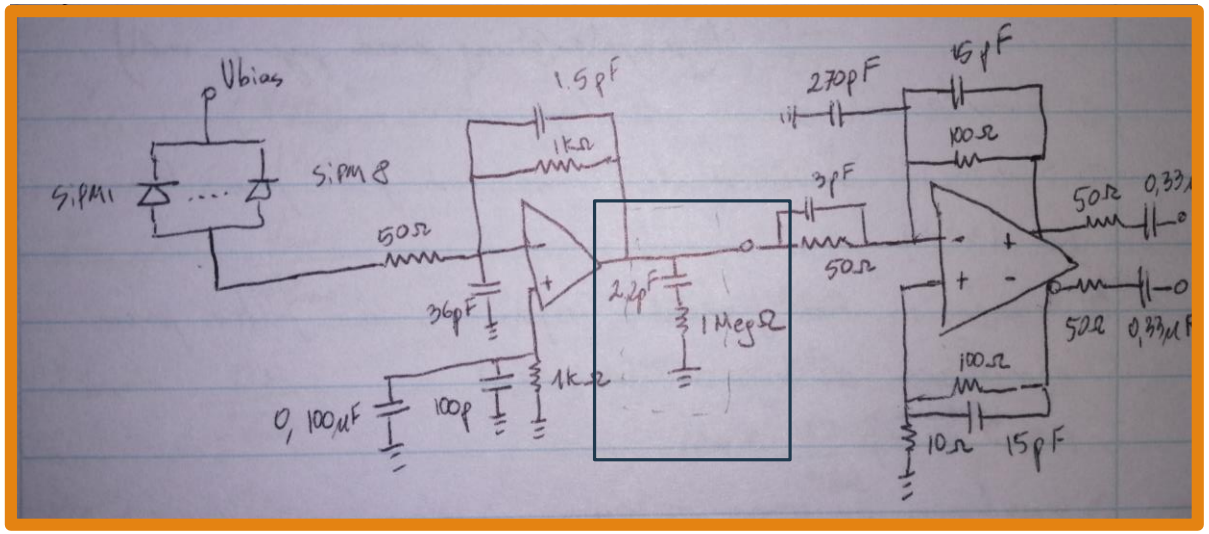
- High frequency, low amplitude oscillatory condition was encountered.
- Signal shape distortion and high amplitude oscillation that was present in V1 was mitigated.
- Nevertheless, this oscillatory condition in V2 prevented the observation of single photoelectron peaks.

Prototype V2 test @ room temperature

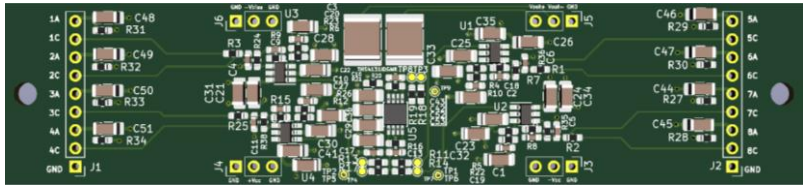


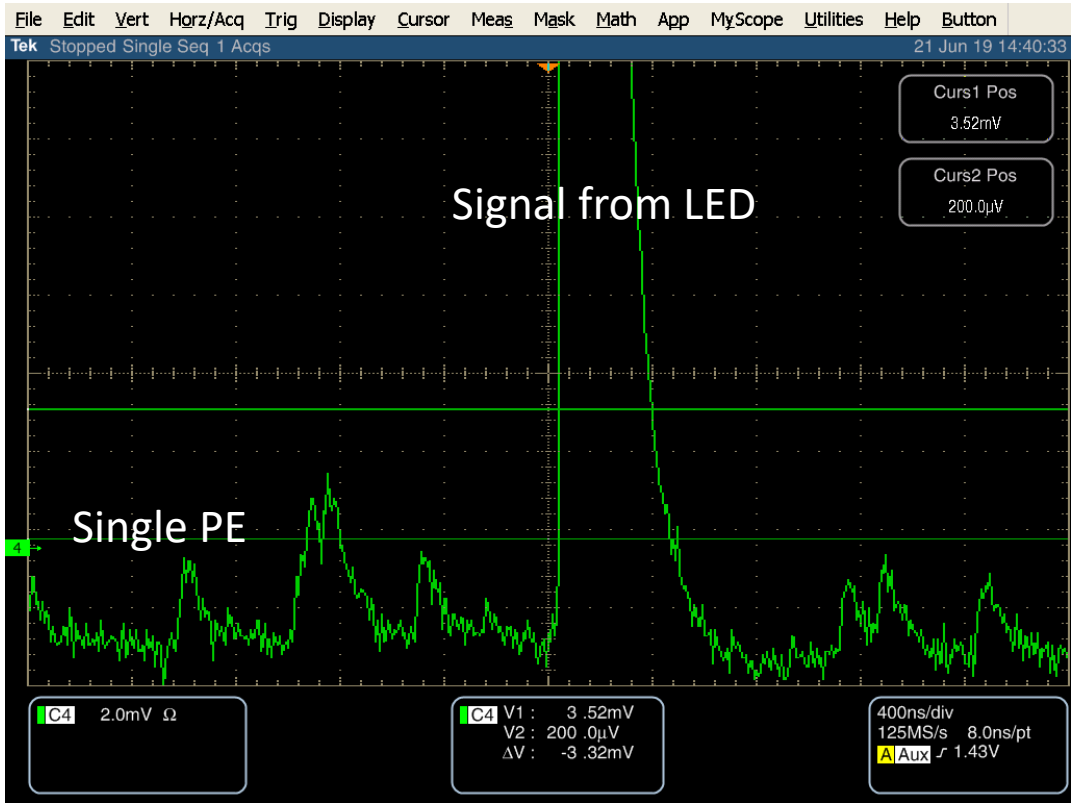


- This oscillations where mitigated by adding a compensation network in between stages.
- The .gif in the right demostrates in real time the effect of adding this compensation.



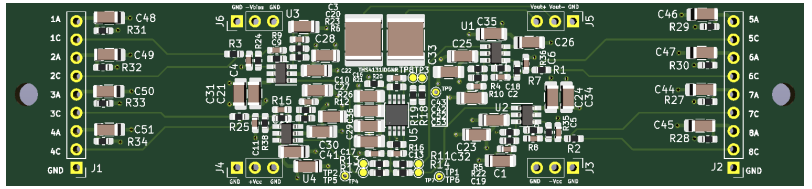
Prototype V2 test @ room temperature



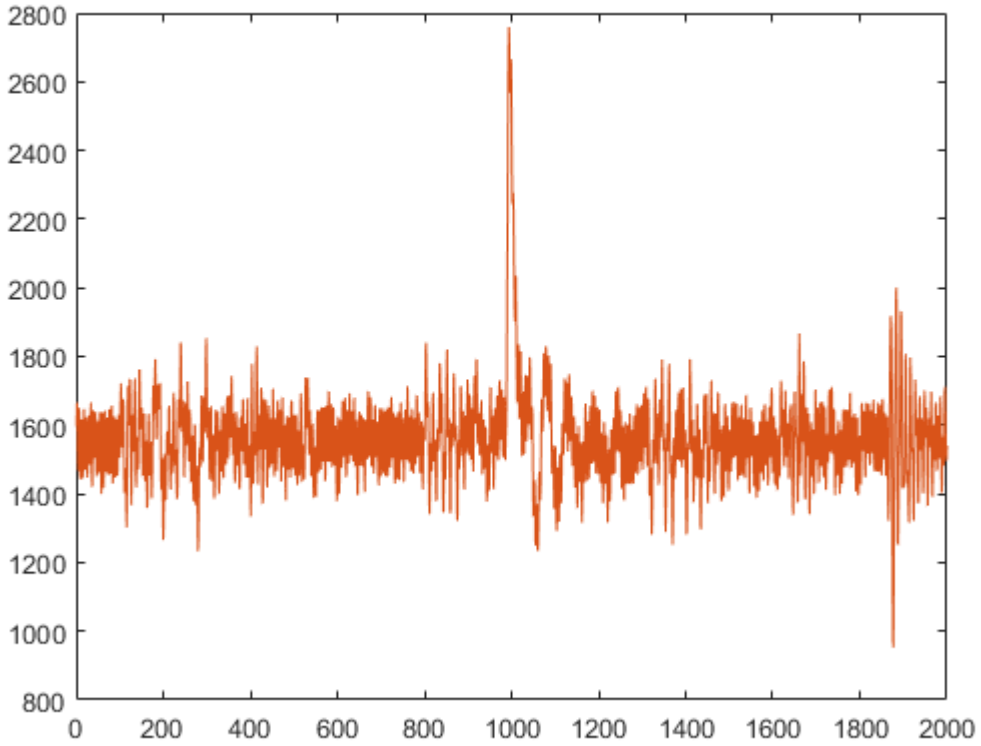


- Single PE resolution is achieved at room temperature @ 20 V/V gain.

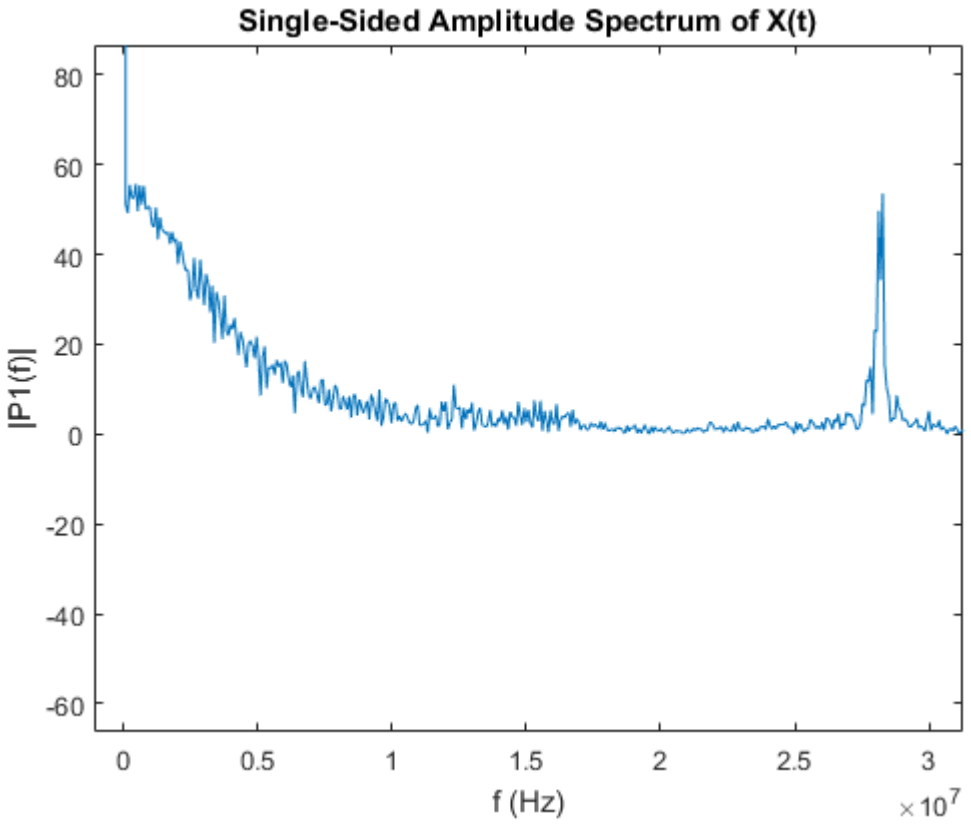
Prototype V2 test @ LN2



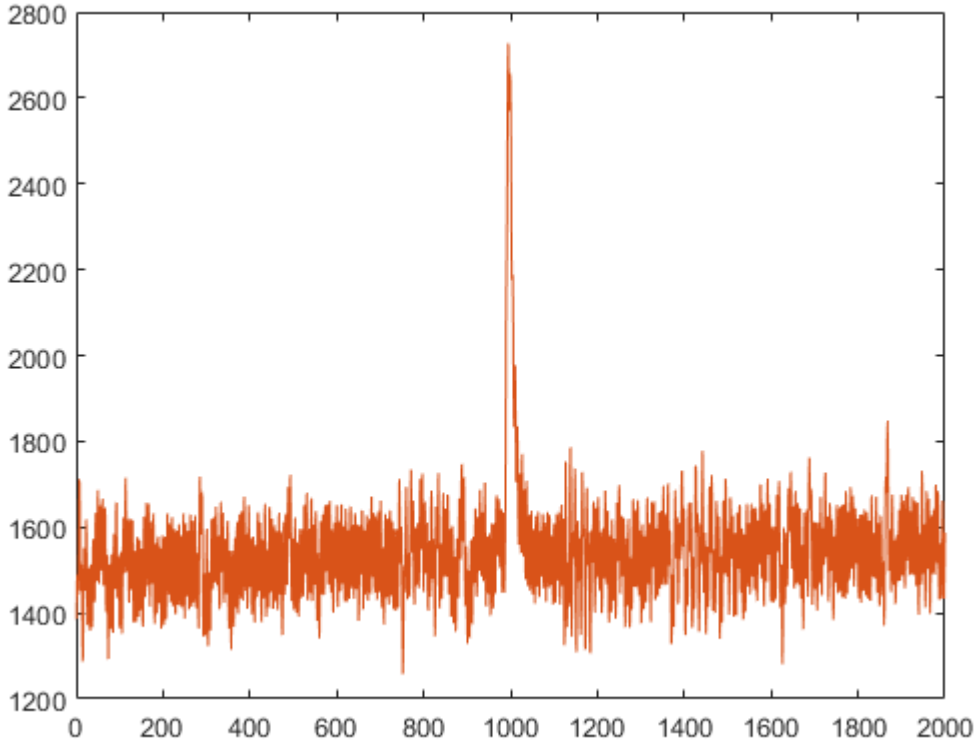
Single PE - 1 MMPC – AMP @ LN2



1 tick = 6.6667 ns

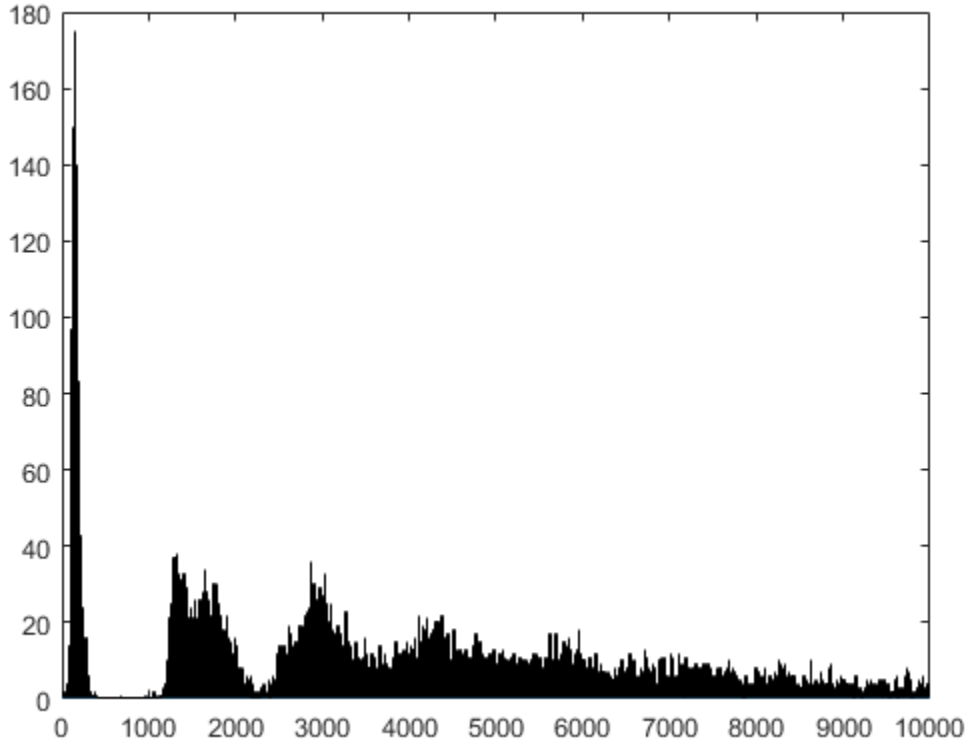


Single PE - 1 MMPC – AMP @ LN2

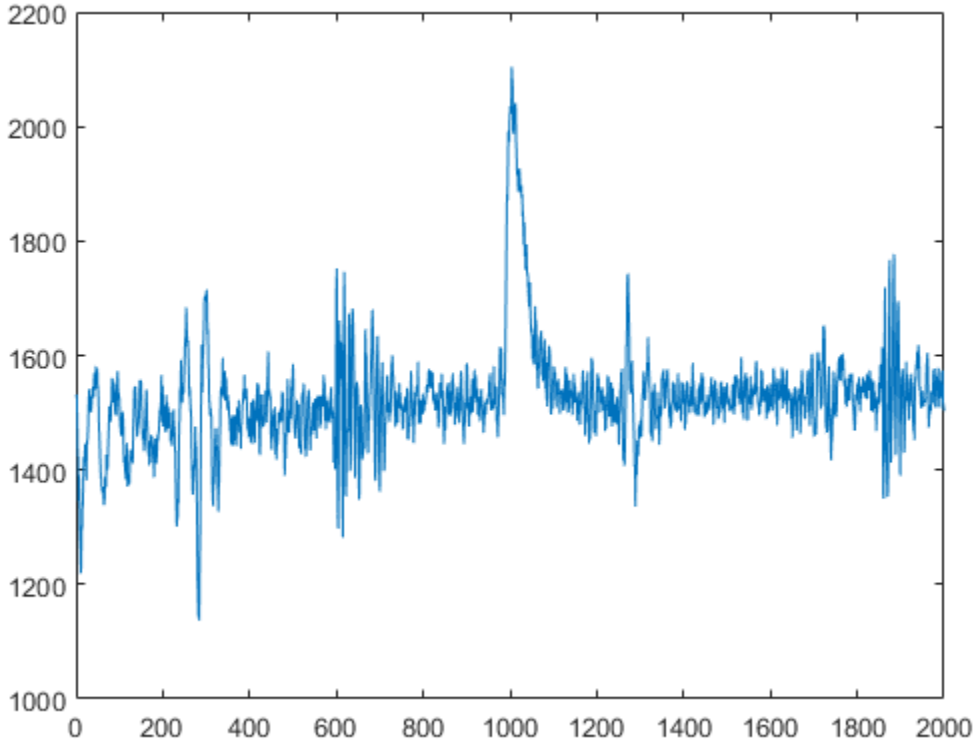


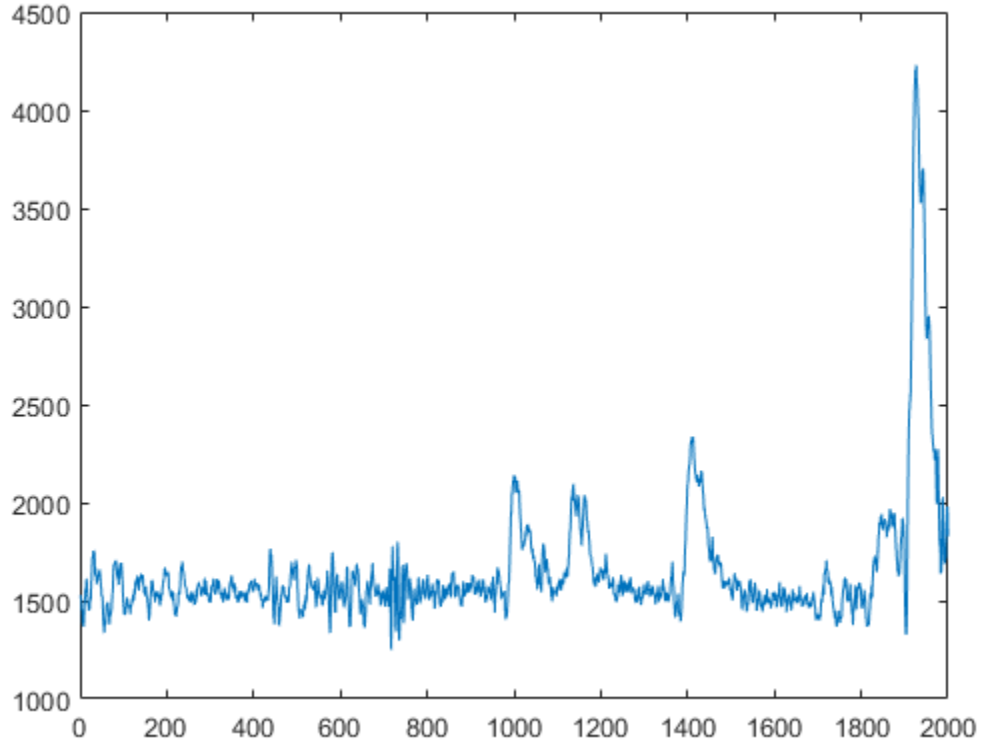
1 tick = 6.6667 ns

Histogram of acquired signals



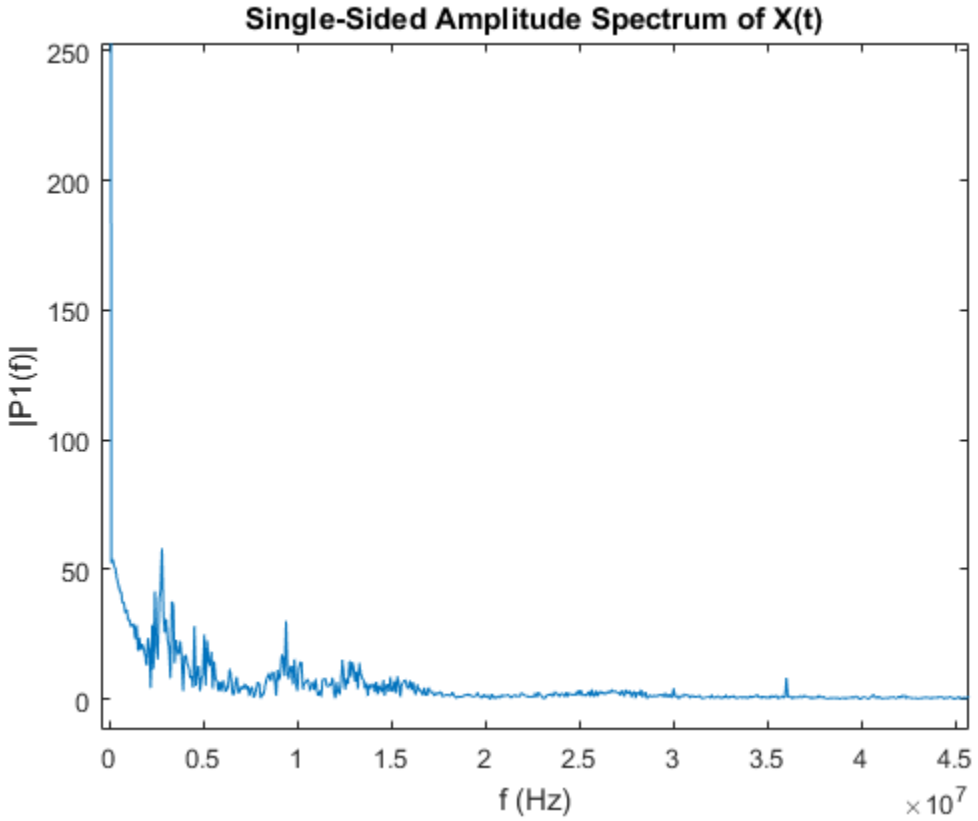
Single PE - 8 MMPC – AMP @ LN2



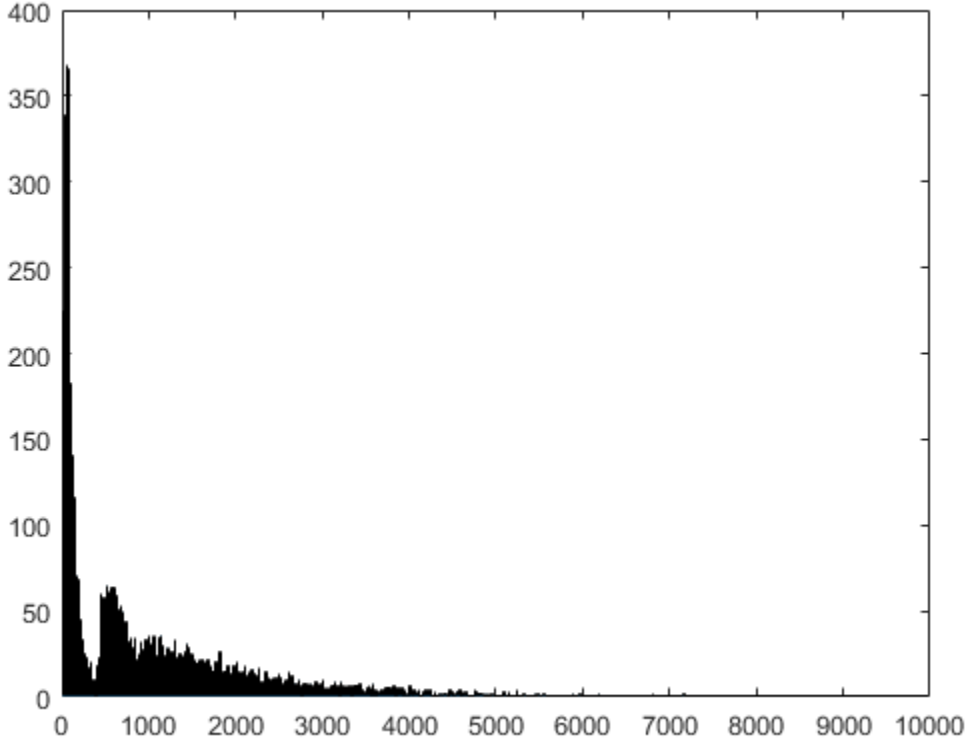


1 tick = 6.6667 ns

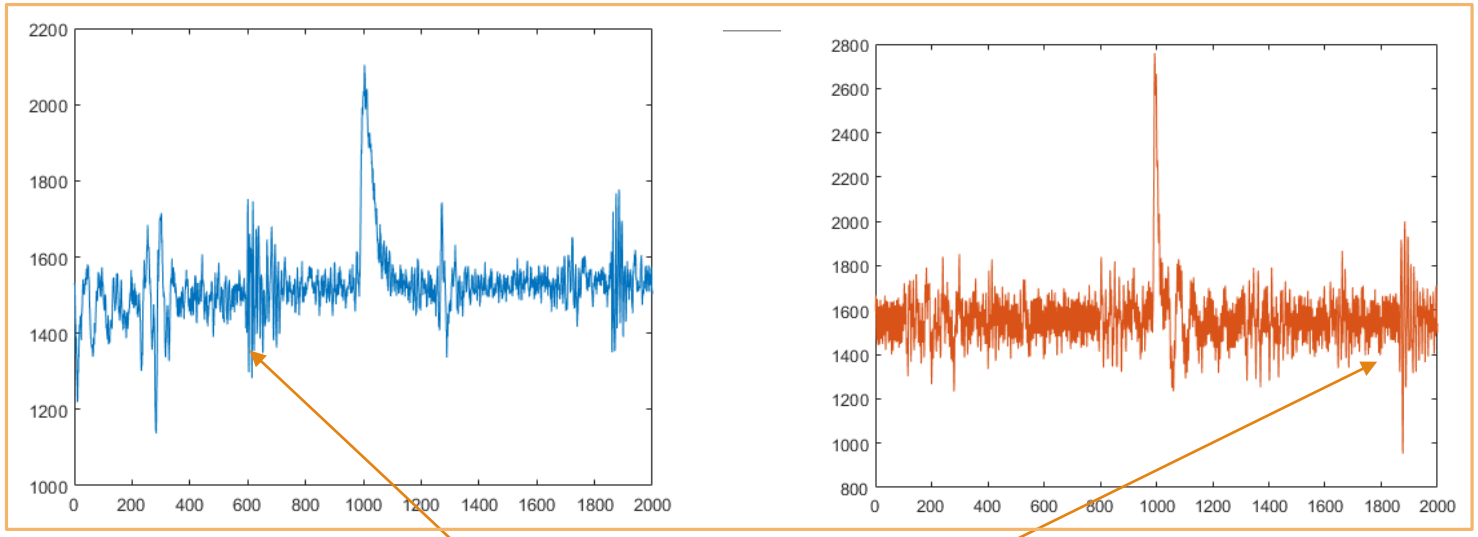
8 MMPC – AMP @ LN2

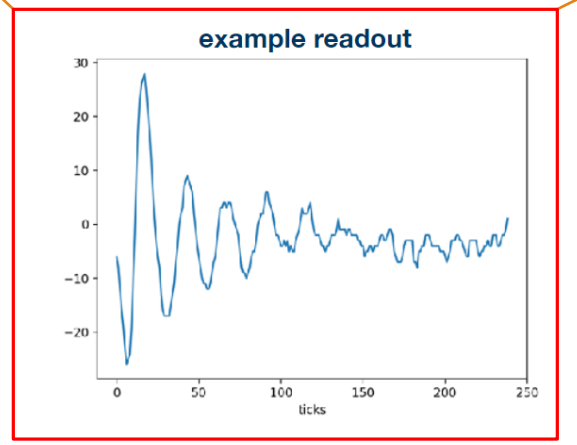


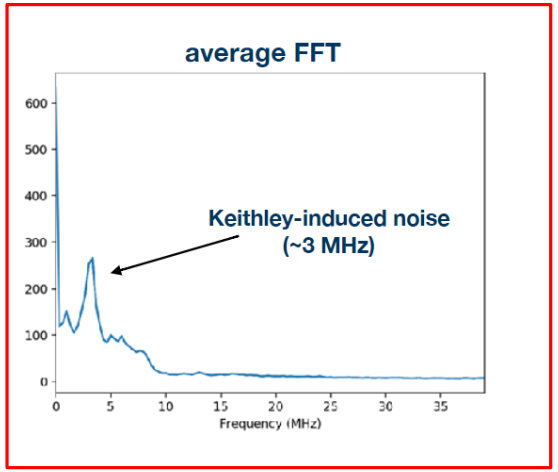
Histogram of acquired signals

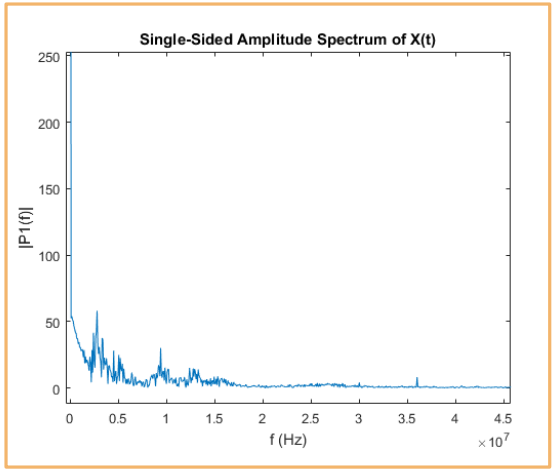


Sources of Noise





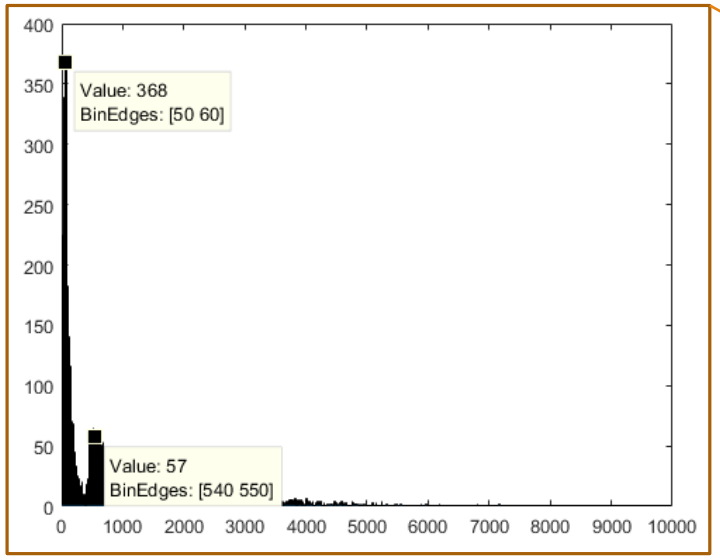


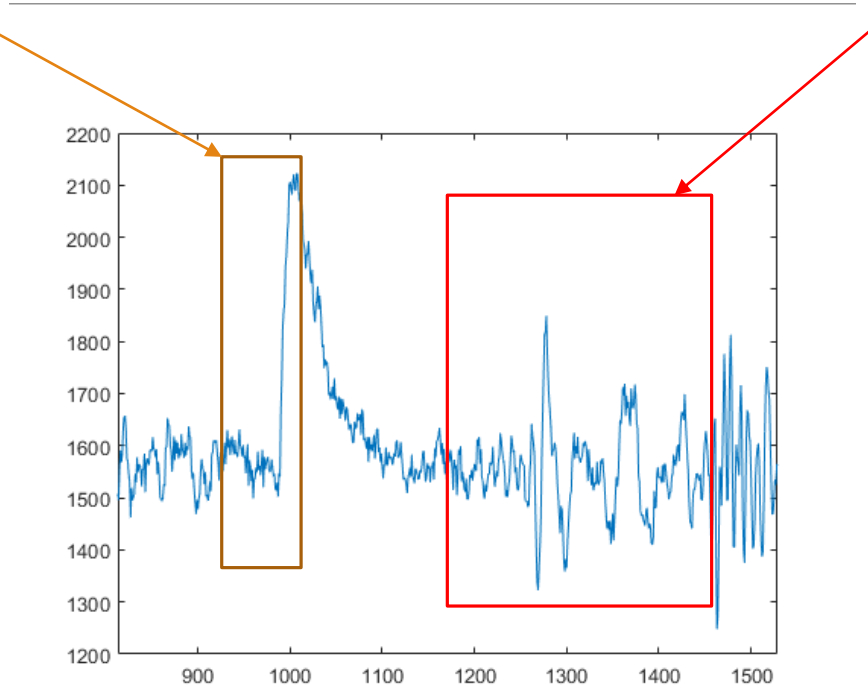


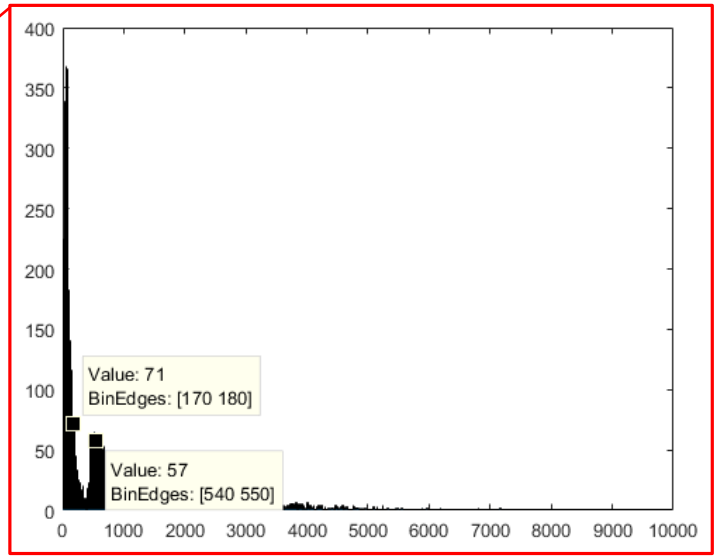
Acquired signals

Noise studies in PAB
https://indico.fnal.gov/event/21034/
Rory Fitzpatrick

Noise Levels





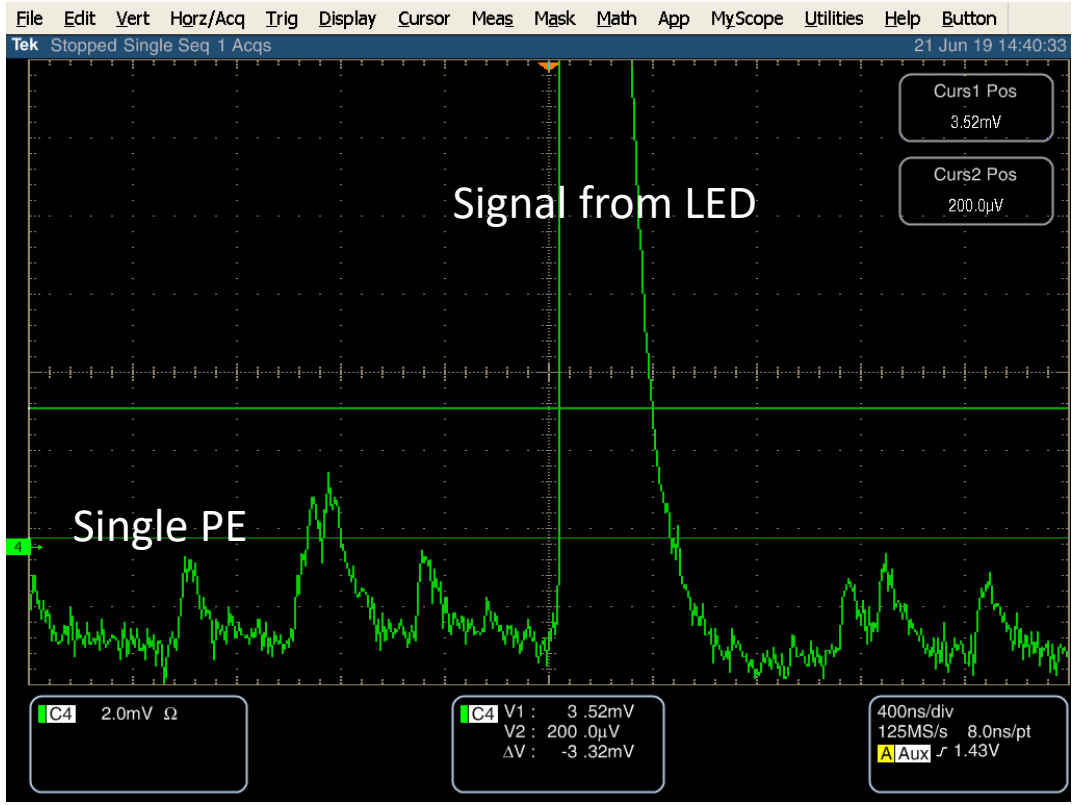


$$SNR = 20log_{10}\left(\frac{540}{60}\right) = 19{,}08 \text{ dB}$$

$$SNR = 20log_{10}\left(\frac{540}{180}\right) = 9{,}5 \text{ dB}$$

As for now, I can say that this the max SNR is about 9,5 dB due to noise introduced by the environment, and can be optimized to achieve 19 dB.

Dynamic Range



- The Dynamic range depends on the first stage (OPA847)
- The OPA847 saturates at around 4V and considering that a single PE from 1 SiPM connected @ Vbias 55V and gain of 20 V/V is 2mV peak at room temp.
- In this case the dynamic range is about 2000 photons, but increasing the number ganged SiPM increases the dynamic range in detriment of SNR.
- Of course, at cryo temperatures the SiPM gain changes and for now I don't feel confident to throw a number.
- Using a good compensation scheme, the gain in the first stage can be lowered to 4 V/V, which will add more dynamic range.
- Using the second amplification stage or a third passive attenuator stage, it could be possible to obtain a required dynamic range.