Thoughts on the KlauS ASIC

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Analog Front End

- We originally priced out the TI AFE5807 8 channel analog front end chip
  - The mu2e cosmic ray veto uses a variant of this chip (several versions exist)
- Alfons Weber has found an interesting existing ASIC (KlauS) which could potentially be adapted.
  - Intended use is calorimetry
- **Conclusions in advance:** I believe both can be made to work, although neither is perfect.

The AFE5807 chip is used commercially in ultrasound and sport fishing sonar.

There are similar products for radar and shortwave (software-defined-radio).

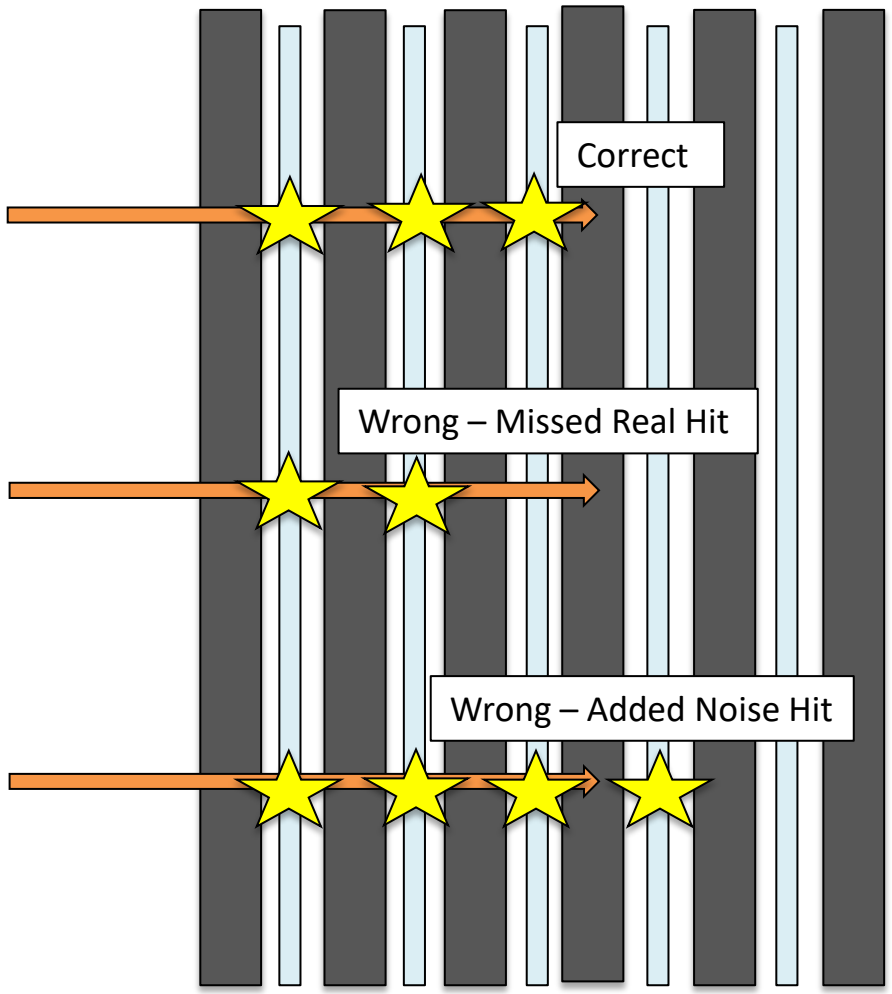
I have not found a better alternative, but confess I haven't looked very hard.

Comparison

	AFE5807	KlauS
Cost	$170,000 (base)	Potentially in-kind from Germany
Channel count	8	32 (need 48)
ADC	12-bit	10/12-bit
Sample Time	12.5 ns	Sample and hold “0.2 ns”
Deadtime	Deadtimeless	Average 3-4% (but see later slide)
System Power	1 kW	< 100 W
Input	Single-ended	Single-ended
Support Circuitry Impact	Unknown	Unknown

- Green is better, gray is good enough, red is potentially troublesome

Noise & Efficiency

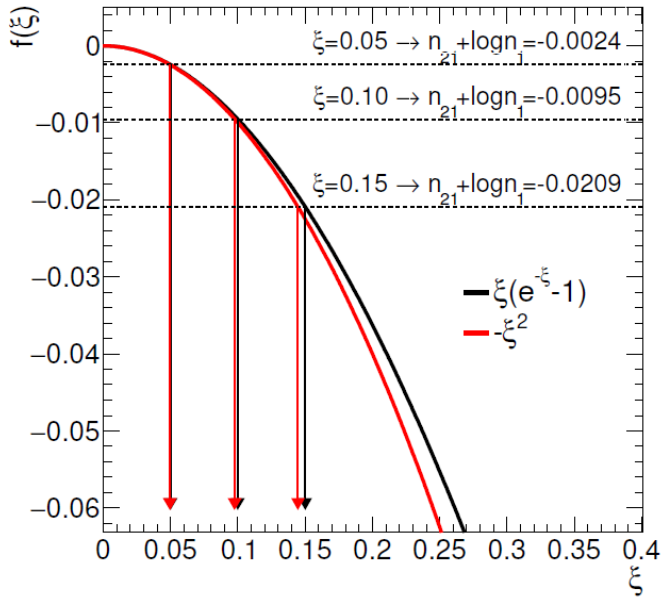


- TMS measures momentum by range
  - Missing the last hit causes us to underestimate the momentum → keep the threshold low
  - Adding an extra hit at the end causes us to overestimate the momentum → keep the threshold high
  - Both can be corrected for statistically, but small corrections are better than large ones
- An important decision will be the operating point
  - Likely to be chip dependent.

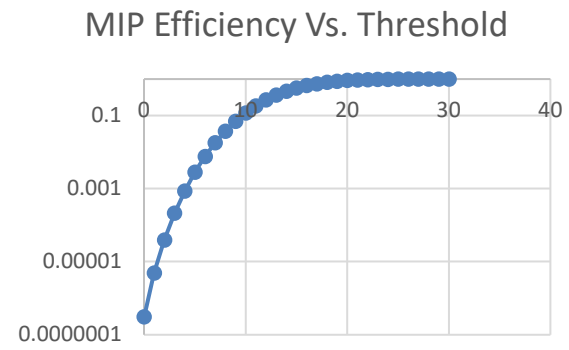
If the TMS is a pure downstream tracker, this is not too complicated – we'll end up at around ½ mip. (Zero is too low…one is too high) If we start looking at dE/dx, this gets more interesting.

Deadtime and the Operating Point

- Originally I had not considered deadtime
  - Commercial front-end chips can handle our rates with no deadtime
  - However, noise is still noise – signal pulses can be distorted
- I would rather have a 99% efficiency than a 1% deadtime
  - An efficiency is just that – deadtime is correlated with beam intensity, particle location, etc.
- We would probably operate KlausS at a higher threshold than the TI AFE5807
  - Lowers deadtime (at a small cost in efficiency) → that's the tradeoff
  - Looks like ~4 photoelectrons (~¼ mip) would be where we end up – a fraction of a percent of each (not the 3-4% at the lower threshold)

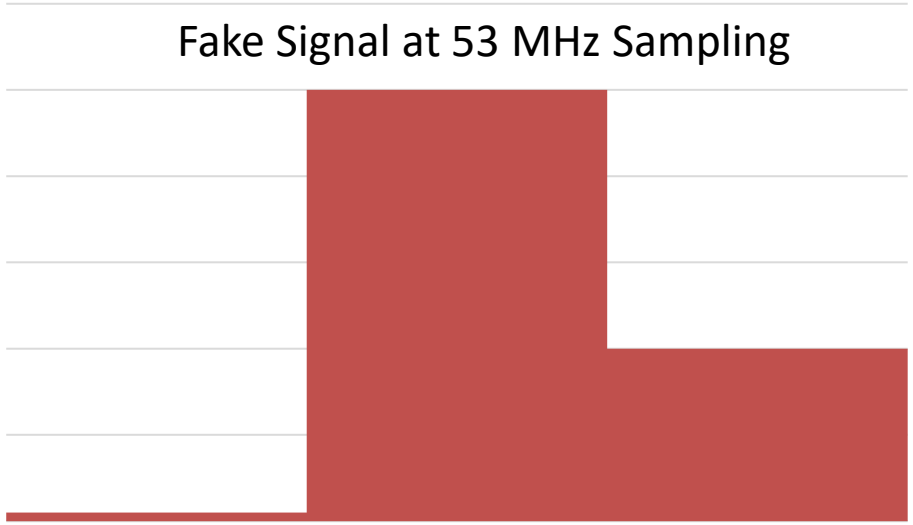


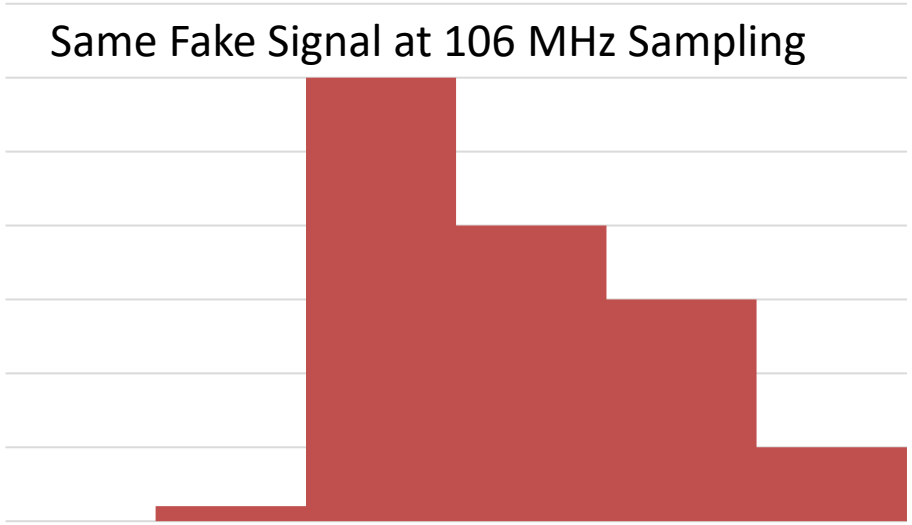
SiPM noise model
(arXiv:1710.11410v1)



Why Does Sample Time Matter?

- Signal formation time is ~30-40 ns.





- With 106 MHz, you can do so-called “optimal filtering” – take the four or five measurements and quickly convert them to ΣQ, t_0, and χ^2.
  - With 80 MHz (AFE5807), you can do this, but “even” events look different than “odd” events – offset by ½ an RF bucket. Probably more trouble than its worth.
- How to do this with KlauS’ sample and hold remains to be seen.

Summary

- I believe both the TI AFE5807 and KlauS can be made to work, although neither is perfect.
  - The biggest issue with the AFE5807 is speed
  - The biggest issue with KlauS is deadtime
  - Neither seems to be a show-stopper, but both have physics impact
  - There are some other smaller annoyances with each option

- We have not explored the entire commercial chip space
  - “Software defined radio” might be promising, if it can be done in a cost & energy efficient manner

Backup

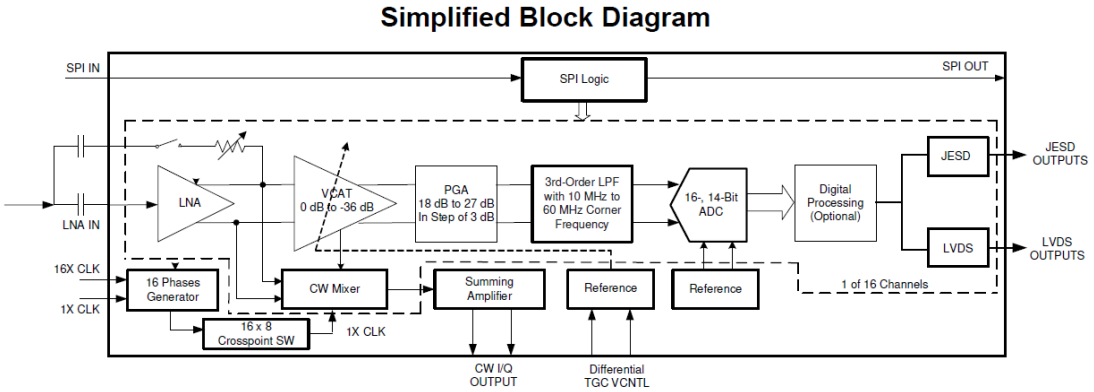
Future Commercial Development

- TI has released a “premium” Analog Front End for ultrasound – AFE58JD48
  - 16 Channels
  - 125 MSPS
  - 16 bit ADC

Both better than we need

- This allows us to do everything the AFE5807 does, but to double-sample the MI clock
- The price is, unfortunately, also “premium”
  - Per channel $19.43 vs. $10.46 – if you can get them at all (35 week lead time)

A chip that does everything we want – and more – is available commercially, but for too much money. Will there be a less-capable and less-expensive chip that does what we want in the future?



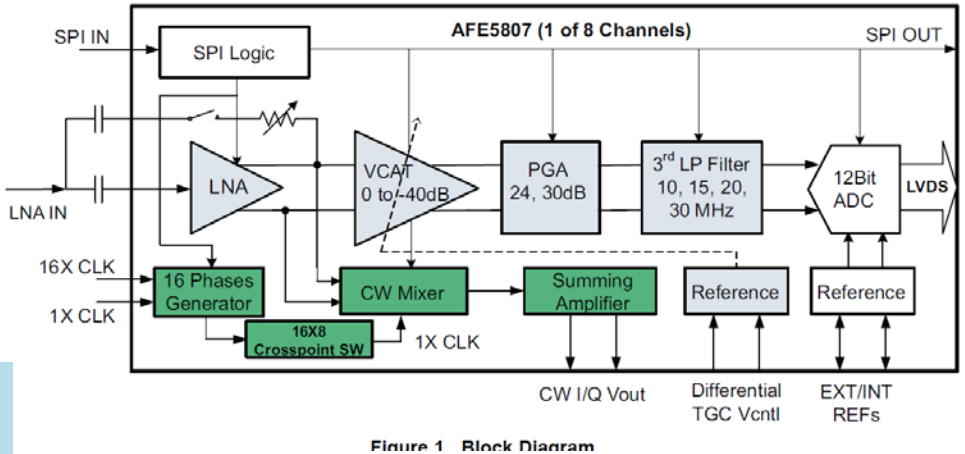


Figure 1. Block Diagram