8CBC2flex hybrid: interference coupling through CF stiffener

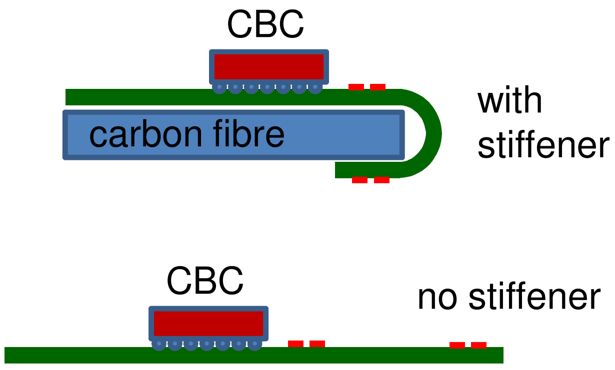
previous presentations:

http://www.hep.ph.ic.ac.uk/~dmray/systems_talks/2016/8cbc2flex_effects.pdf

http://www.hep.ph.ic.ac.uk/~dmray/systems_talks/2016/8cbc2flex_effects_June_2016.pdf

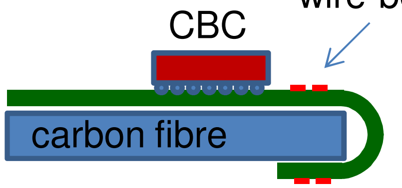
can compare results now for:

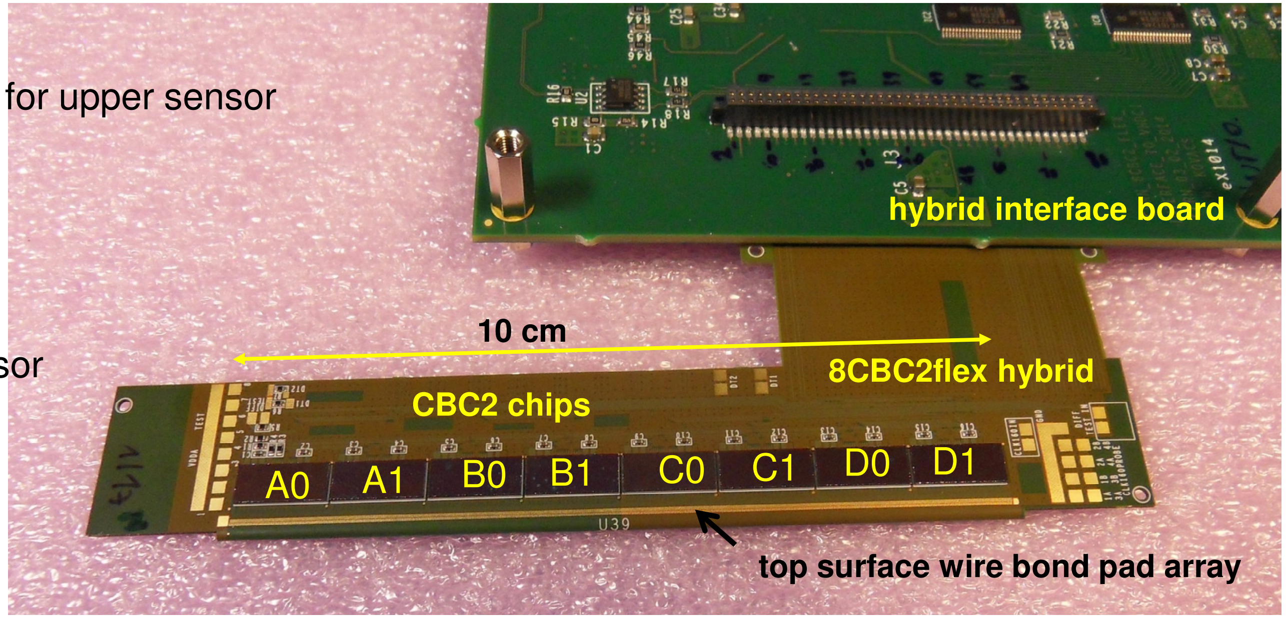
- AEMTEC hybrid mounted on stiffener
- VALTRONIC hybrid mounted on stiffener
- AEMTEC hybrid - no stiffener



Systems meeting, 1st November, 2016

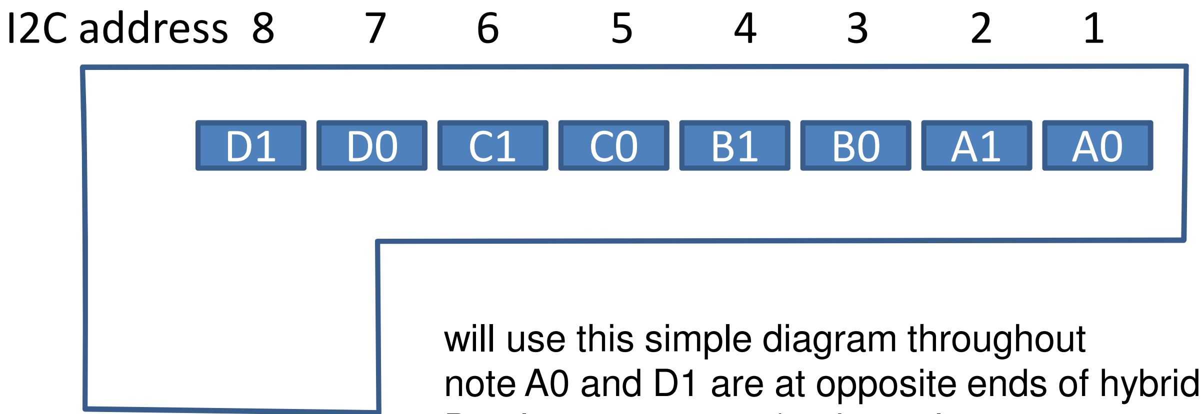
8CBC2flex hybrid chip designations





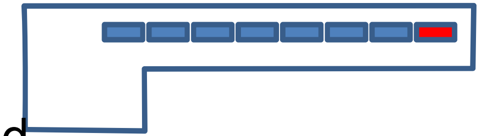
D1 closest to power supply end of hybrid

A0 furthest away



will use this simple diagram throughout
note A0 and D1 are at opposite ends of hybrid
D1 closest to power/gnd supply

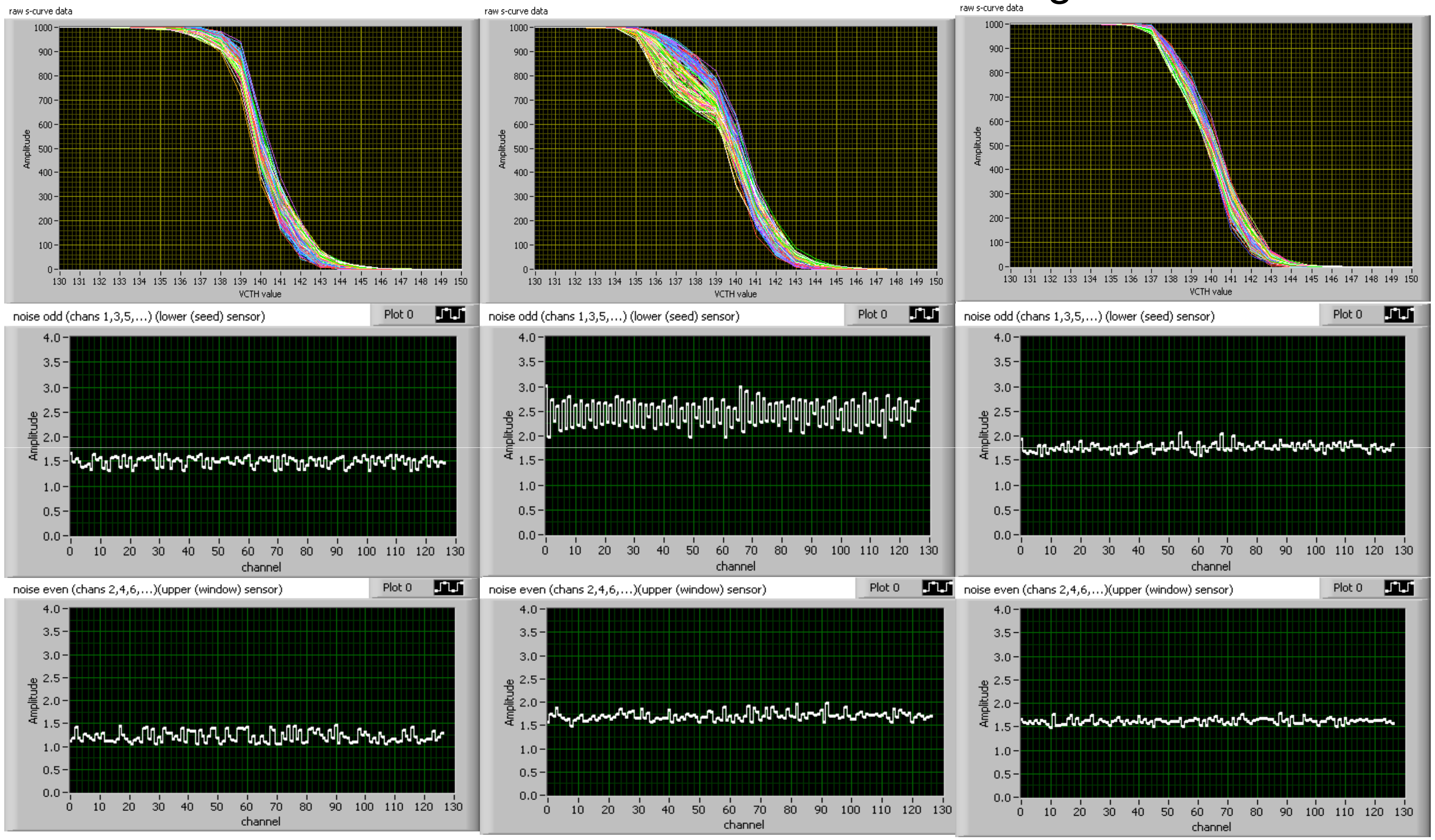
1st effect: s-curve distortions - chip A0



all chans masked

all chans UNmasked

all chans unmasked
CF grounded



AEMTEC hybrid with stiffener

s-curve distortion when channels un-masked from correlation logic

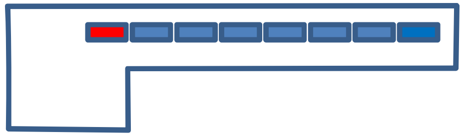
=> trigger line activity on hybrid

alternating high-low effect in noise for lower sensor channels

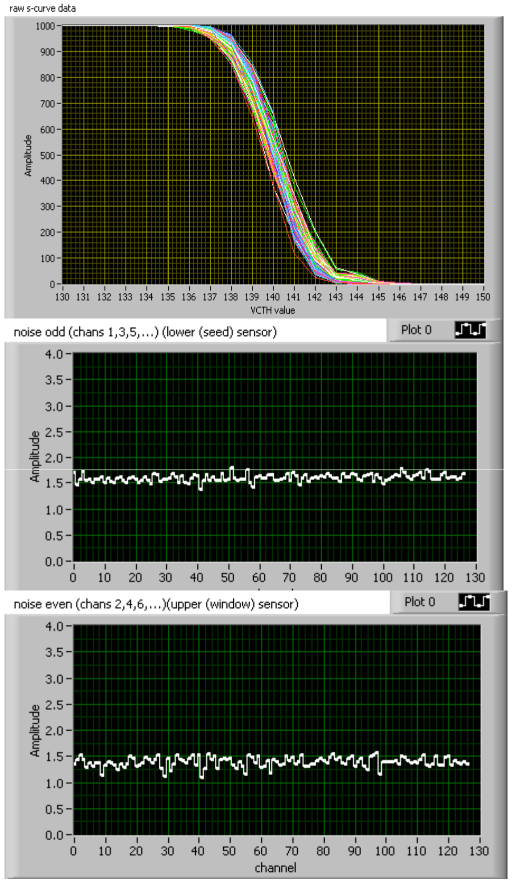
worst affected channels are those tracked round edge of hybrid

effect is significantly reduced if CF stiffener grounded

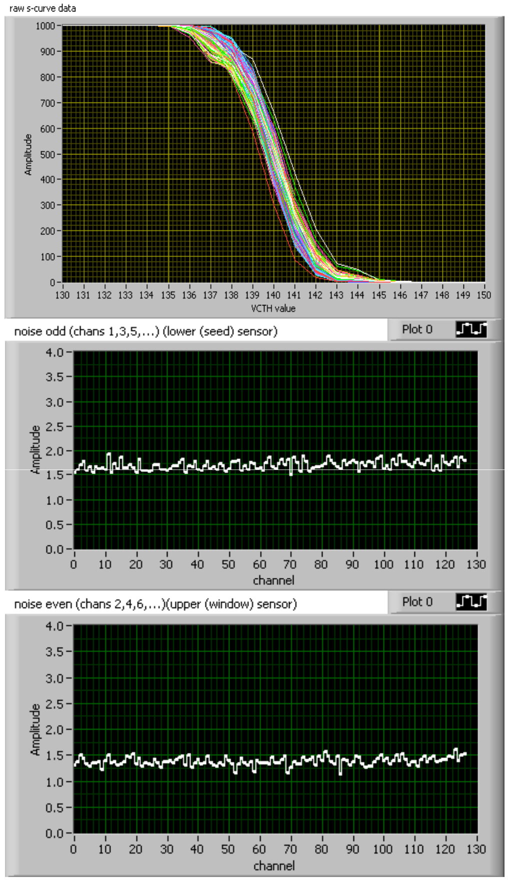
s-curve distortions - chip D1



all chans masked



all chans UNmasked

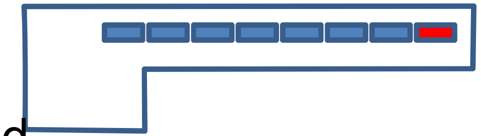


AEMTEC hybrid with stiffener

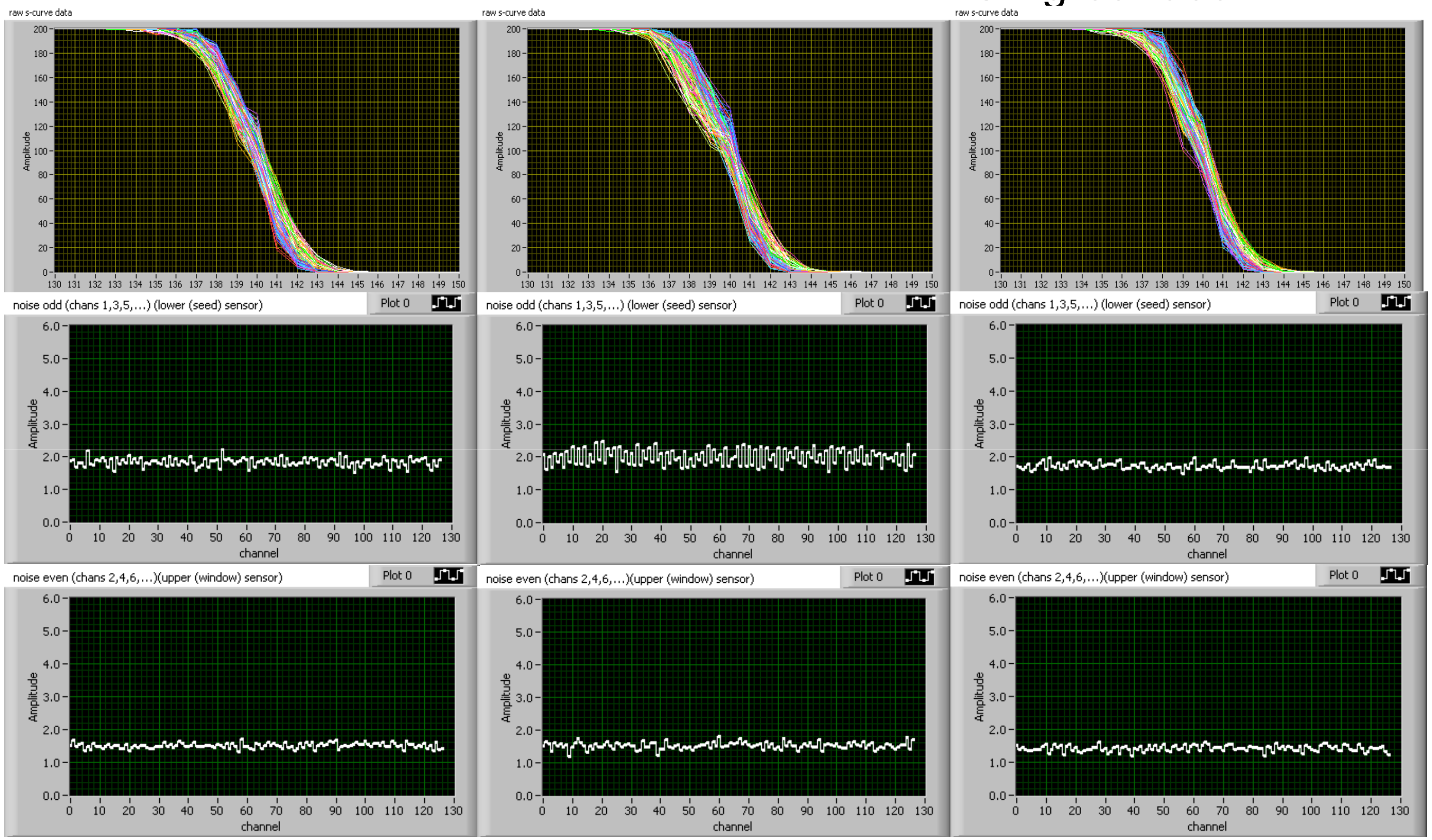
chip D1 shows no significant effect
when channels unmasked

grounding stiffener not necessary

s-curve distortions - chip A0, Valtronic hybrid



all chans masked | all chans UNmasked | all chans unmasked CF grounded



some s-curve distortion when channels un-masked from correlation logic

significantly better than AEMTEC hybrid

grounded stiffener completely eliminates

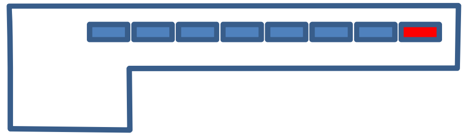
no s-curve distortion effect observed for chip D1

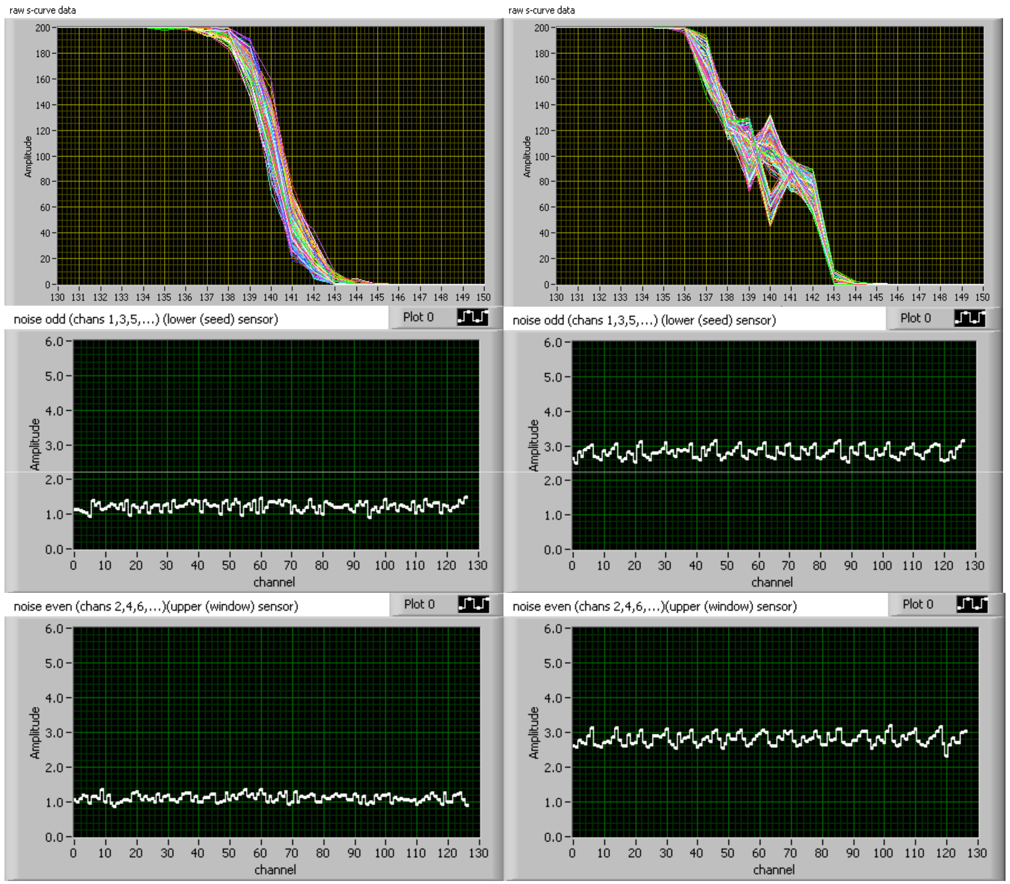
s-curve distortions - chip A0, AEMTEC hybrid, no stiffener

all chans masked

all chans UNmasked

~~CF grounded~~





big s-curve distortion when channels un- masked from correlation logic

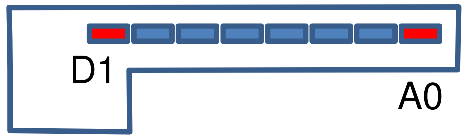
characteristics a bit different from hybrid with stiffener

upper and lower channels affected similarly

(with stiffener lower channels were worse, and there was an alternating channel effect)

once again - no s-curve distortion effect observed for chip D1

summarise s-curve distortion effect



chip	channels status	stiffener status	AEMTEC + stiffener	Valtronic	AEMTEC no stiffener
A0	masked	floating	0	0	0
A0	unmasked	floating	▬ ▬ ▬	▬	▬ ▬ ▬
A0	unmasked	grounded	▬	0	n/a
D1	masked or unmasked	floating or grounded	0	0	0

observations

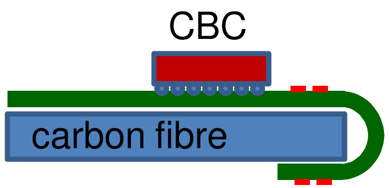
Valtronic hybrid layout better for minimisation of this effect

grounding hybrid is beneficial, but doesn't completely eliminate for AEMTEC

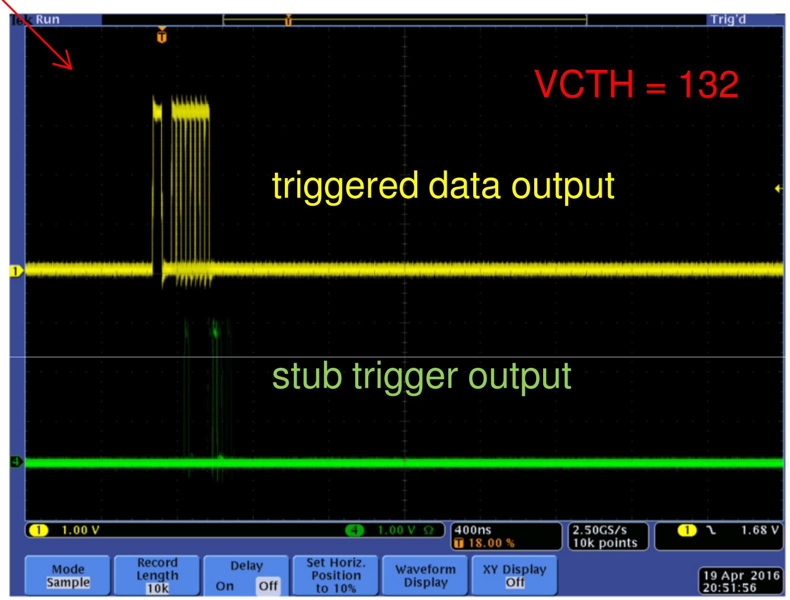
presence of effect doesn't depend on presence/absence of stiffener

but characteristics of effect do depend on presence/absence of stiffener

2nd effect: double trigger effect



(with channels unmasked) observe activity on the trigger line at around the same time as the digital header in the triggered data



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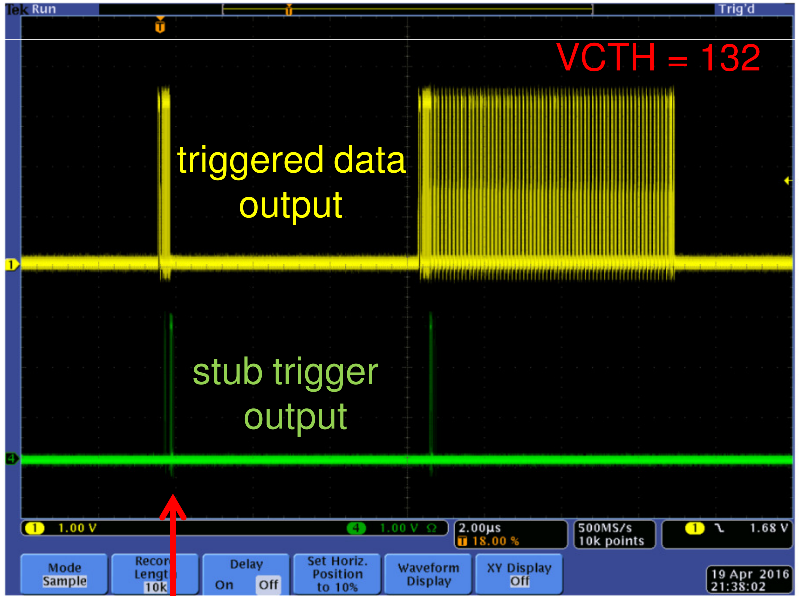
triggering the chip at the digital header time (to see what has caused the trigger line to fire) shows big activity on <u>every 4th channel</u>, corresponding to the channels that are tracked furthest on the hybrid



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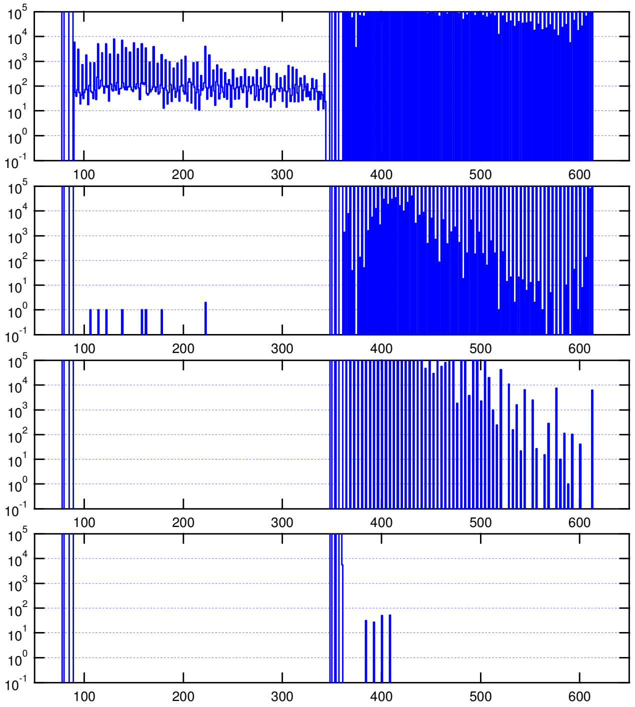
2nd trigger here

double trigger effect: chip A0, AEMTEC hybrid + stiffener

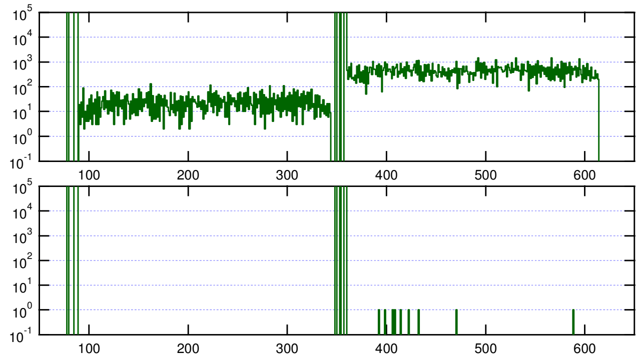


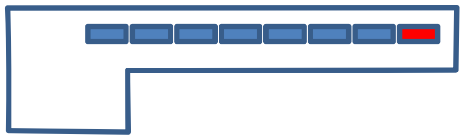
VCTH = 136

VCTH = 132

VCTH = 110

VCTH = 90





note: pedestals set at VCTH = 140, signal is negative going, so lower VCTH = higher threshold

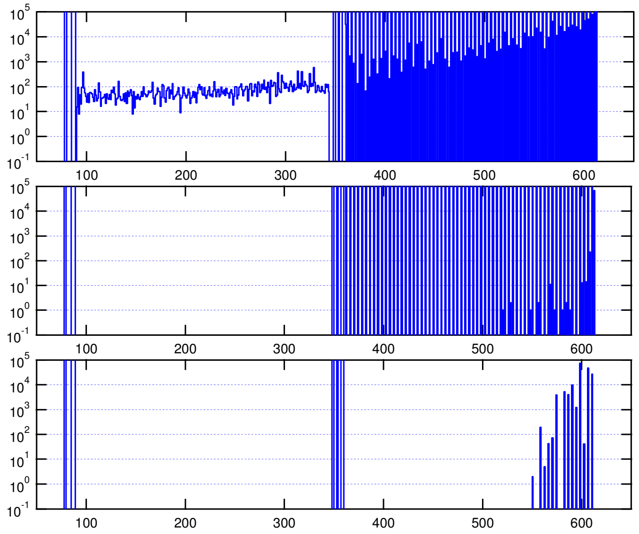
for 10^5 double triggers count no. of times a bit is set in the triggered output data

for low thresholds see some activity in 1st frame, huge activity in 2nd

drops off as threshold increased but have to reach large values

big improvement when stiffener grounded

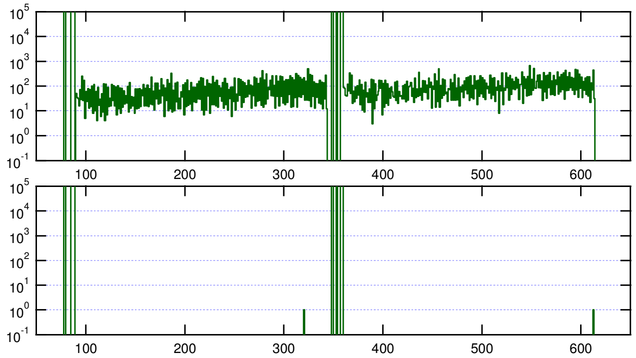
double trigger effect: chip D1, AEMTEC hybrid + stiffener

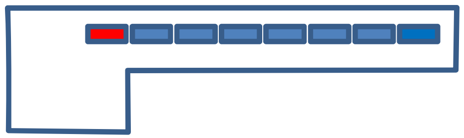


VCTH = 136

VCTH = 132

VCTH = 110

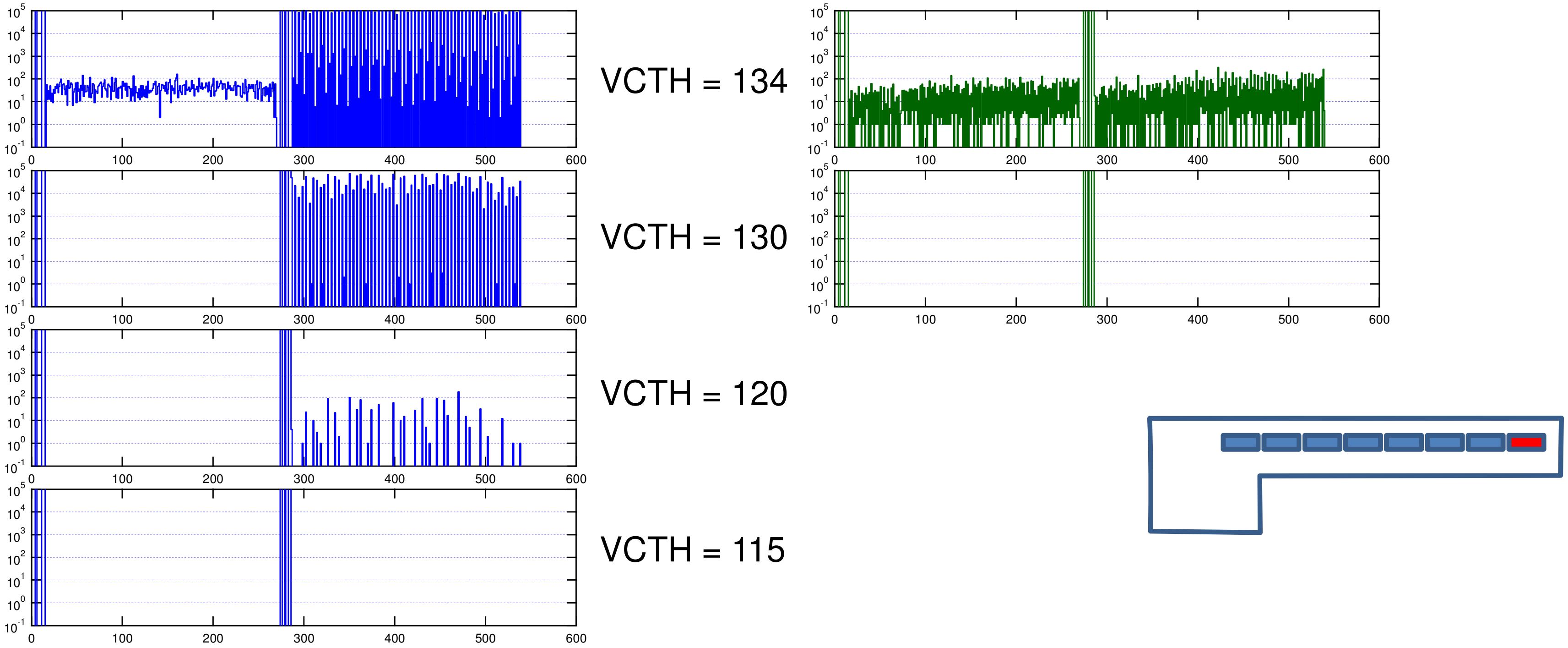




effect still there for D1

grounded CF stiffener eliminates

double trigger effect: chip A0, VALTRONIC hybrid + stiffener



for the bare hybrid, without the additional ground connection, the effect is certainly there

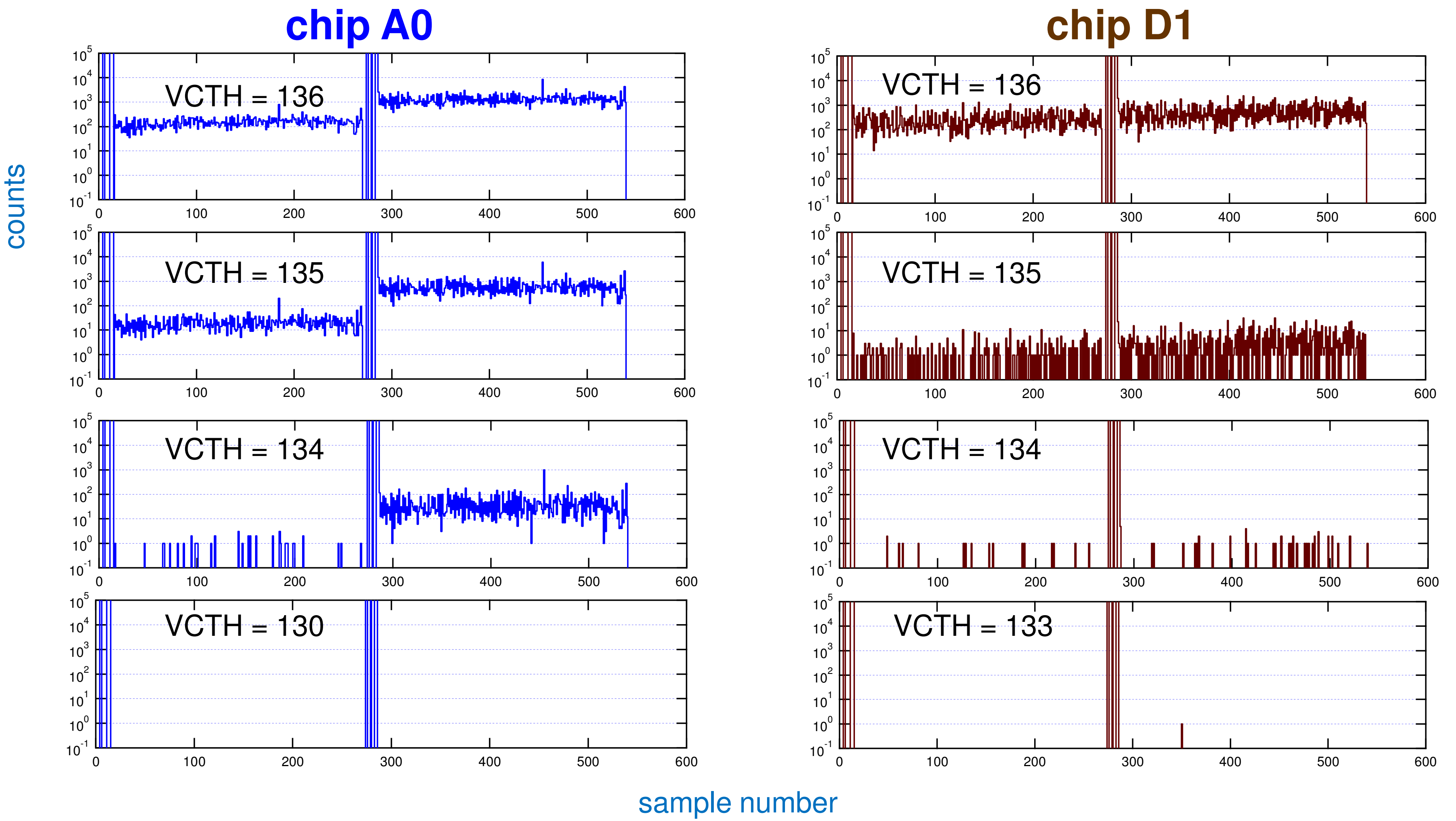
it is significantly less than that observed for the AEMTEC hybrid

but still much too big to live with

grounding the stiffener completely eliminates the effect

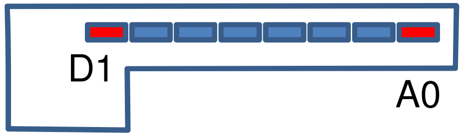
behaviour for chip D1 very similar

double trigger effect: AEMTEC hybrid, no stiffener



the effect is **much** smaller without the presence of the stiffener
chip A0 does see some enhancement of hits in the second frame and effect drops off slower with VCTH
chip D1 shows no effect at all

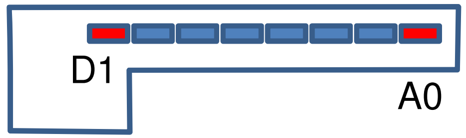
summarise double triggger effect



chip	stiffener status	AEMTEC + stiffener	Valtronic	AEMTEC no stiffener
A0	floating	▬ ▬ ▬ ▬	▬ ▬ ▬	▬
A0	grounded	▬	0	
D1	floating	▬ ▬ ▬	▬ ▬	0
D1	grounded	0	0	

observations

- the stiffener is strongly implicated in aggravating this effect
- digital activity is coupling to the stiffener and subsequently back into the chip inputs
  - => chips at both ends of the hybrid are affected
- grounding the stiffener is necessary



so two “separate” effects

chip	channels status	stiffener status	AEMTEC + stiffener	Valtronic	AEMTEC no stiffener
A0	masked	floating	0	0	0
A0	unmasked	floating	▬ ▬ ▬	▬	▬ ▬ ▬
A0	unmasked	grounded	▬	0	n/a
D1	masked or unmasked	floating or grounded	0	0	0

s-curve distortion

strongly affects chips furthest from power supply end of hybrid

strongly dependent on hybrid layout

grounding hybrid significantly improves performance for these chips

chips at power supply end not affected

chip	stiffener status	AEMTEC + stiffener	Valtronic	AEMTEC no stiffener
A0	floating	▬ ▬ ▬ ▬	▬ ▬ ▬	▬
A0	grounded	▬	0	
D1	floating	▬ ▬ ▬	▬ ▬	0
D1	grounded	0	0	

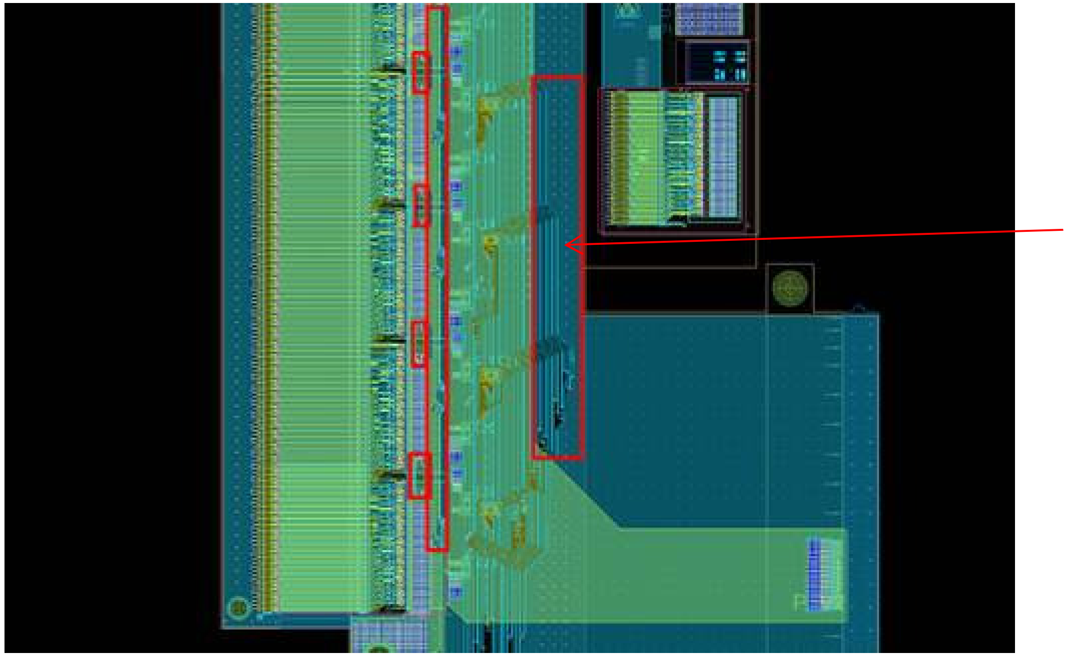
double trigger effect

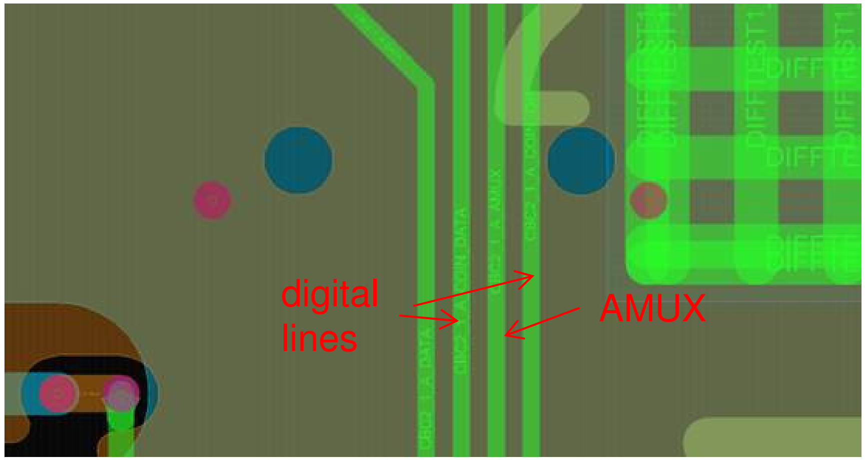
affects all chips on hybrid

stiffener is implicated

grounding stiffener ~eliminates

message from Mark Kovacs*





* my simplification of more detailed thoughts and analysis

looking for exposed digital traces that could lead to effects that might get worse for chips further from power supply end

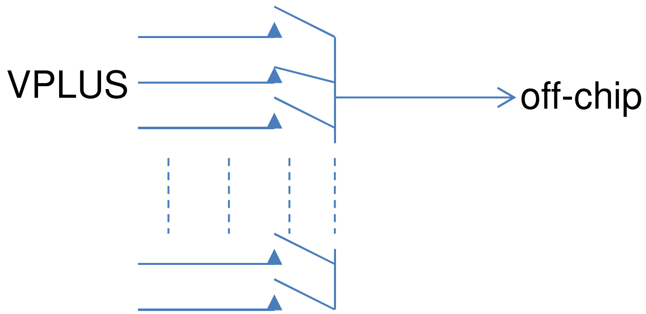
peak area of exposed traces nearest to D0, C1, C0 on AEMTEC and VALTRONIC hybrids (much less on VALTRONIC) so shouldn't lead to worst effects for A0

looking for something that correlates with distance from connector

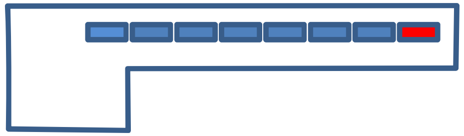
AMUX line is routed with digital lines on both hybrids - trace length growing with distance from power connector

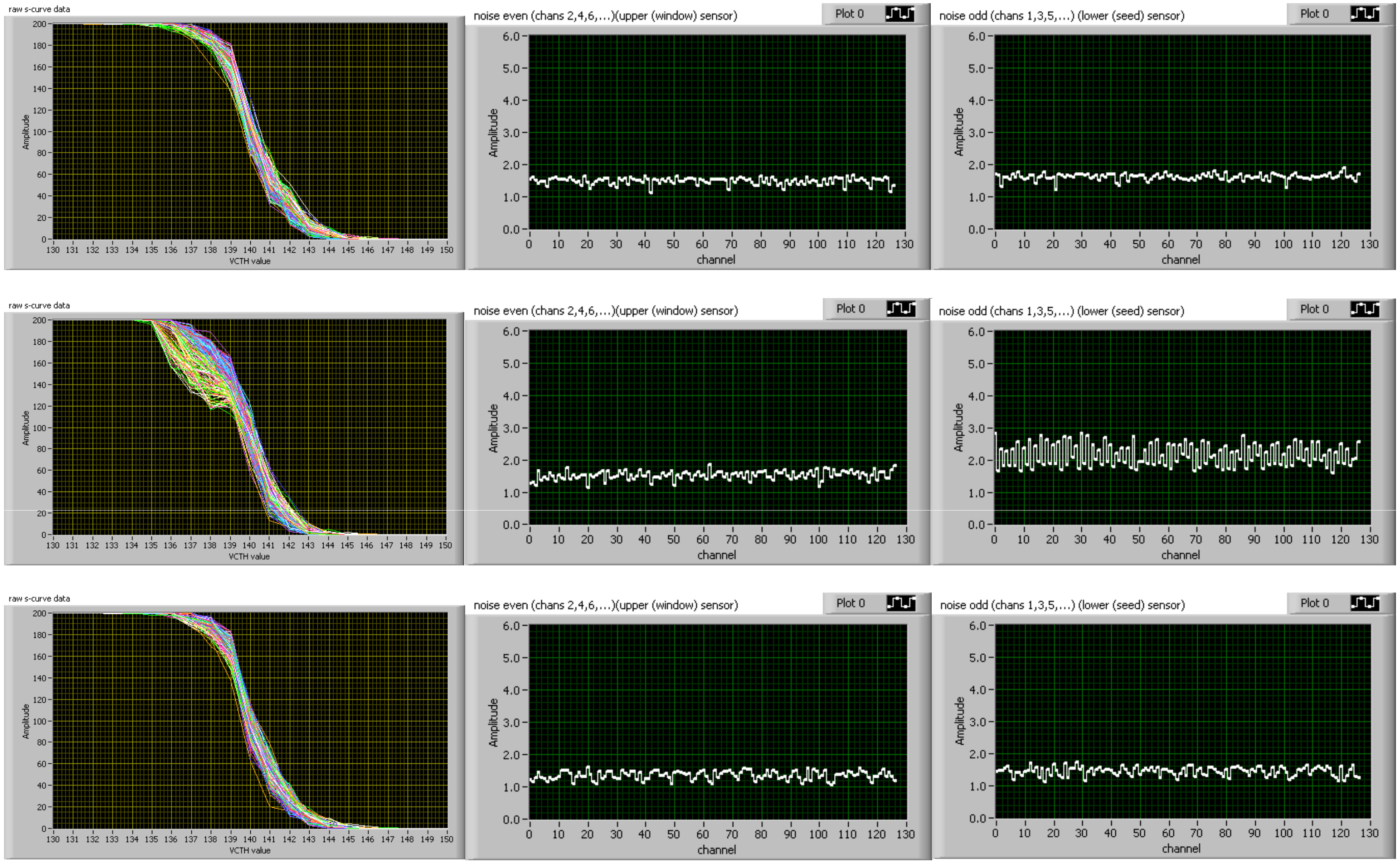
suggested to measure effects with AMUX ON and OFF

AMUX usually set to VPLUS to externally decouple this signal to remove CM effects



AEMTEC with stiffener: chip A0





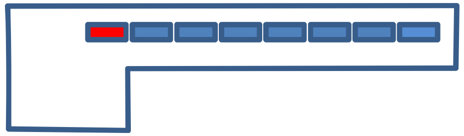
VPLUS selected
all channels
masked

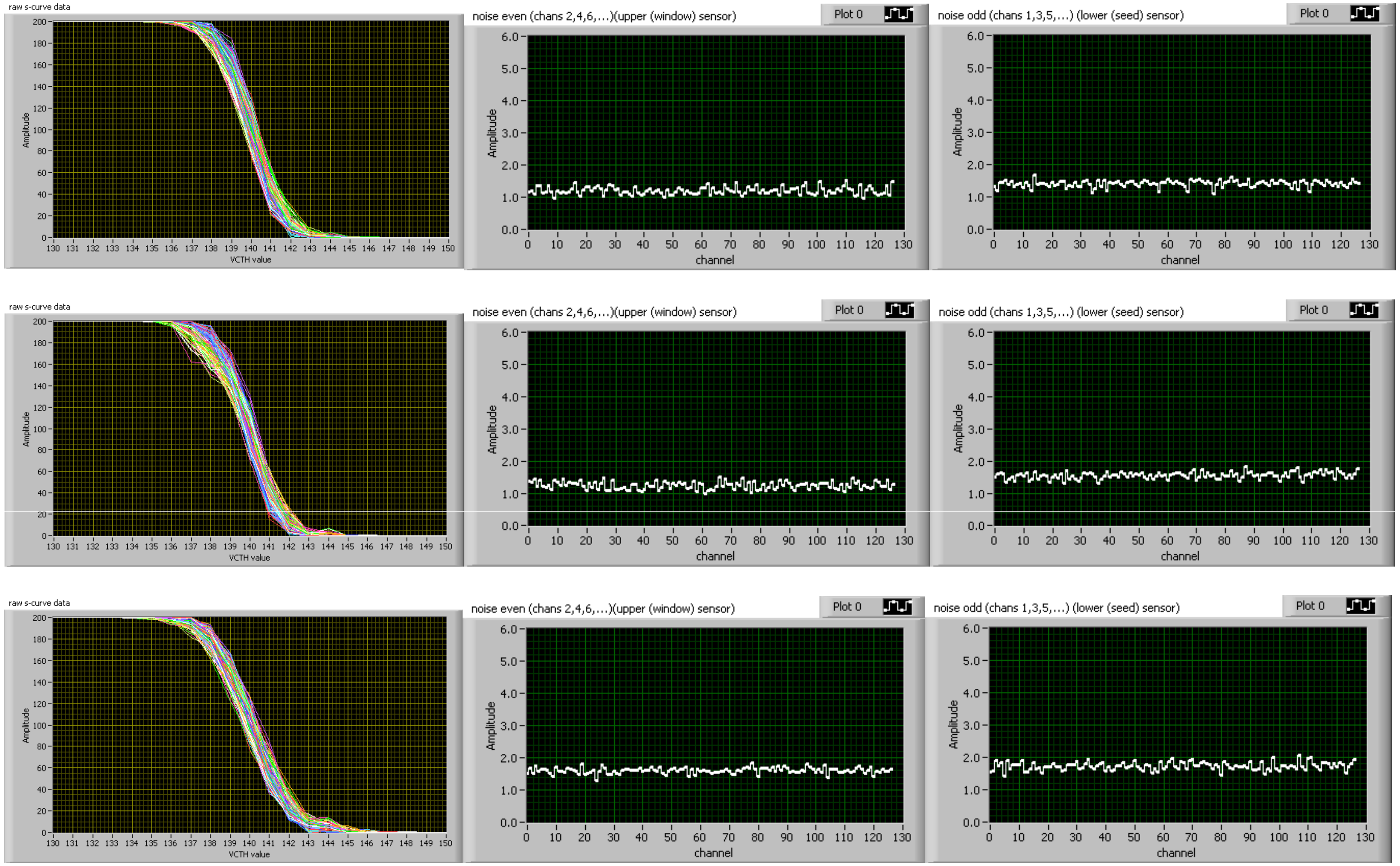
VPLUS selected
all channels
unmasked

VPLUS unselected
all channels
unmasked

s-curve distortion effect **does** depend on whether AMUX line is connected or not

AEMTEC with stiffener: chip D1





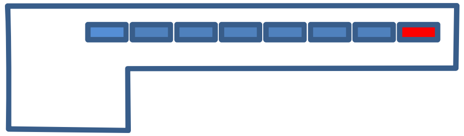
VPLUS selected
all channels
masked

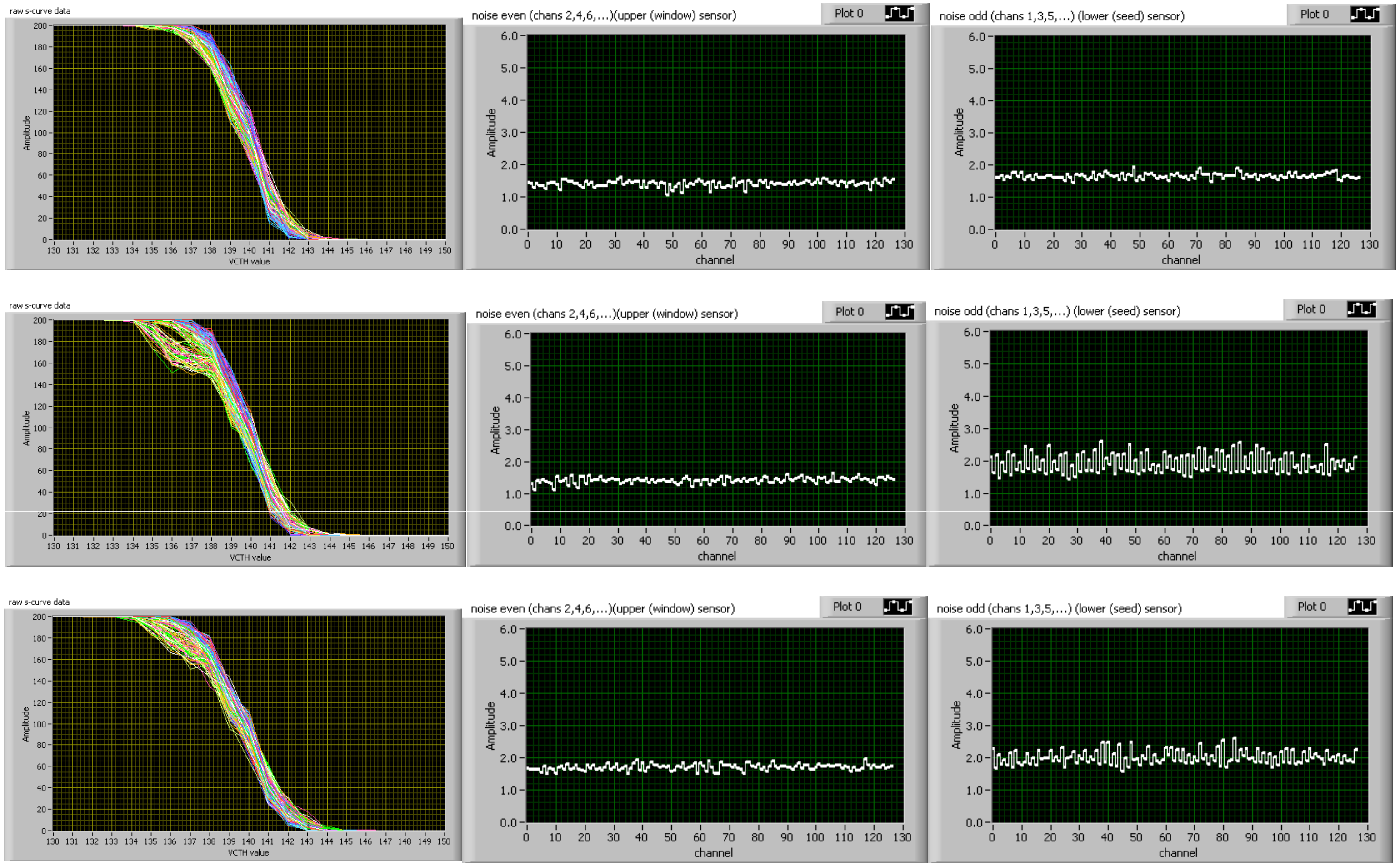
VPLUS selected
all channels
unmasked

VPLUS unselected
all channels
unmasked

not much difference for D1 - slight enhancement of noise with VPLUS unselected
(probably CM effect)

VALTRONIC (with stiffener) A0





VPLUS selected
all channels
masked

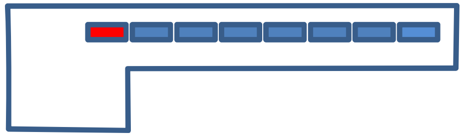
VPLUS selected
all channels
unmasked

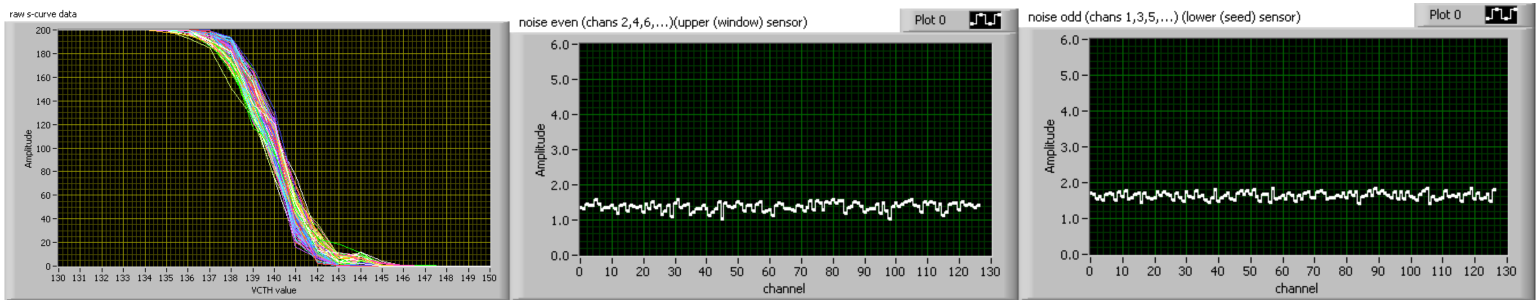
VPLUS unselected
all channels
unmasked

~similar observations as for A0 on AEMTEC with stiffener

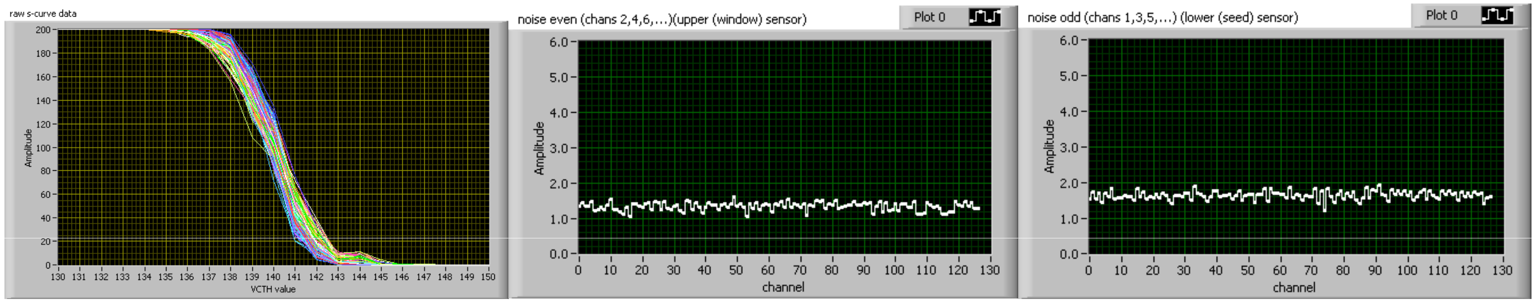
s-curve distortion effect **does** depend on whether AMUX line is connected or not

VALTRONIC (with stiffener) D1

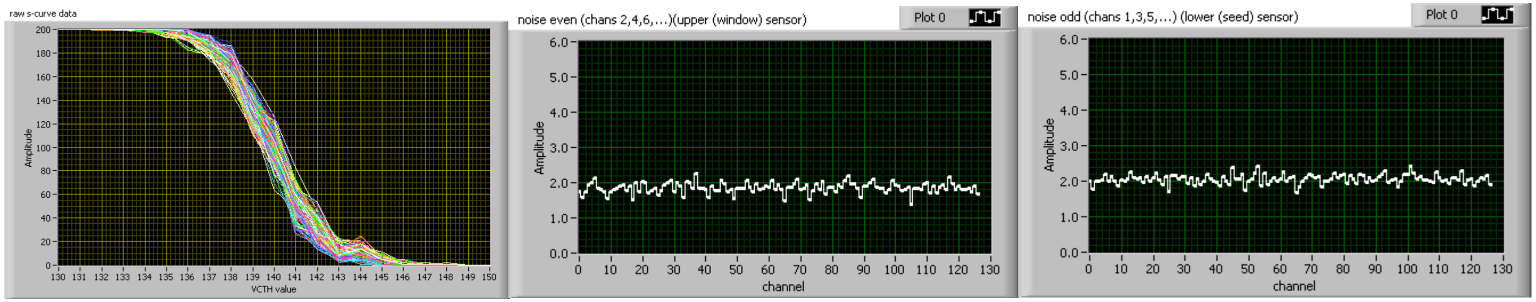




VPLUS selected
all channels
masked



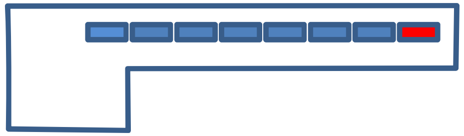
VPLUS selected
all channels
unmasked

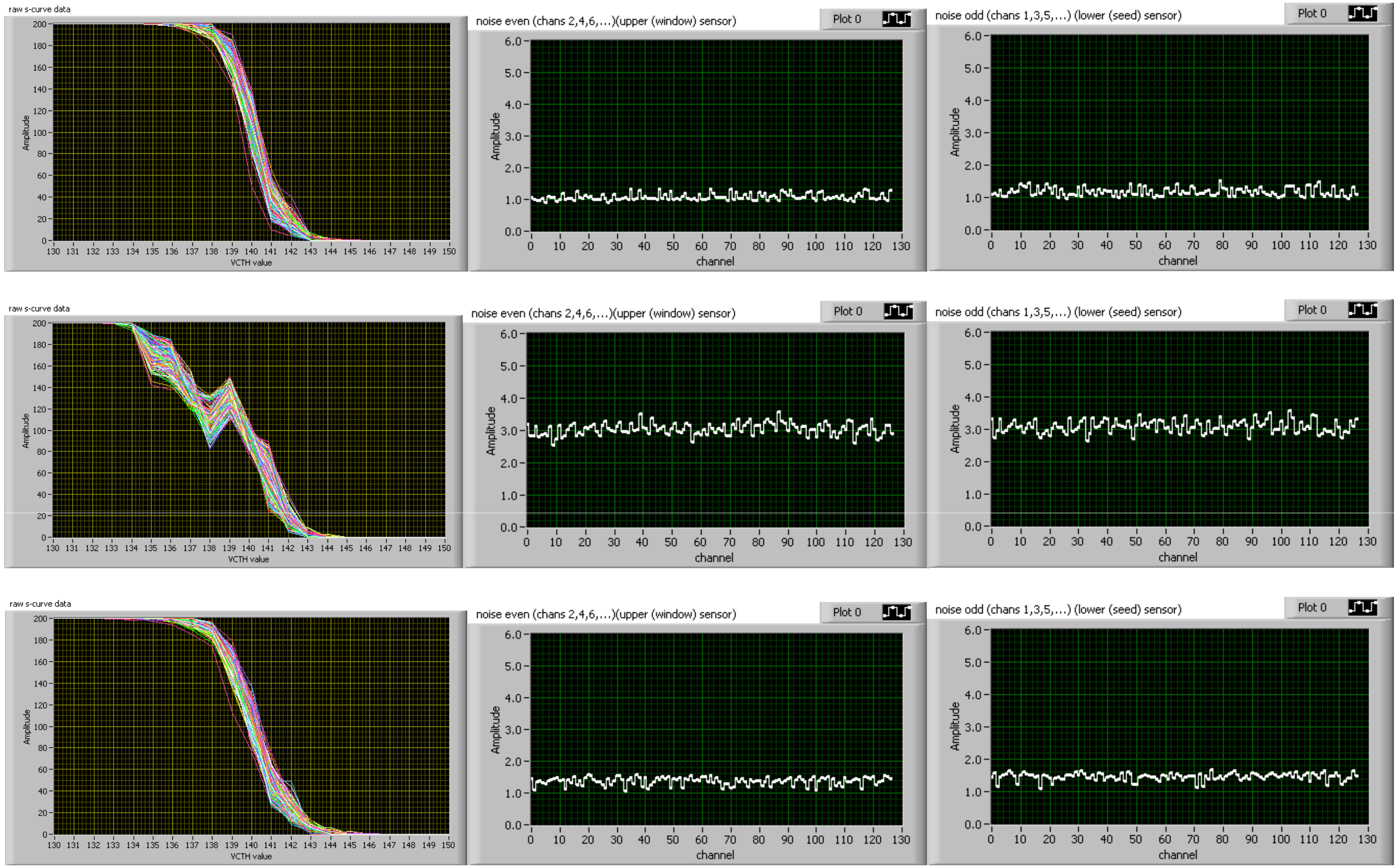


VPLUS unselected
all channels
unmasked

similar observations as for D1 on AEMTEC with stiffener

AEMTEC (without stiffener) A0





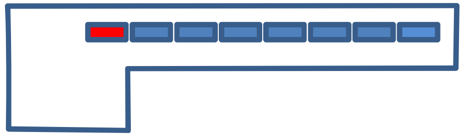
VPLUS selected
all channels
masked

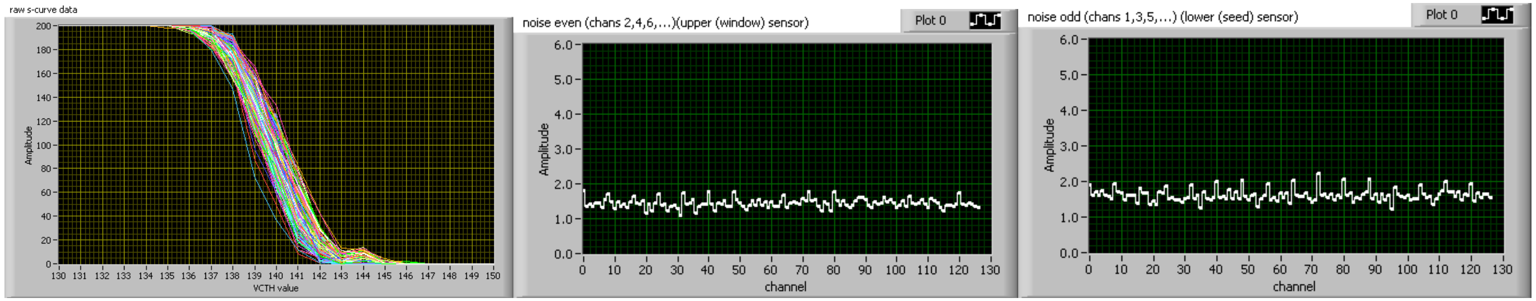
VPLUS selected
all channels
unmasked

VPLUS unselected
all channels
unmasked

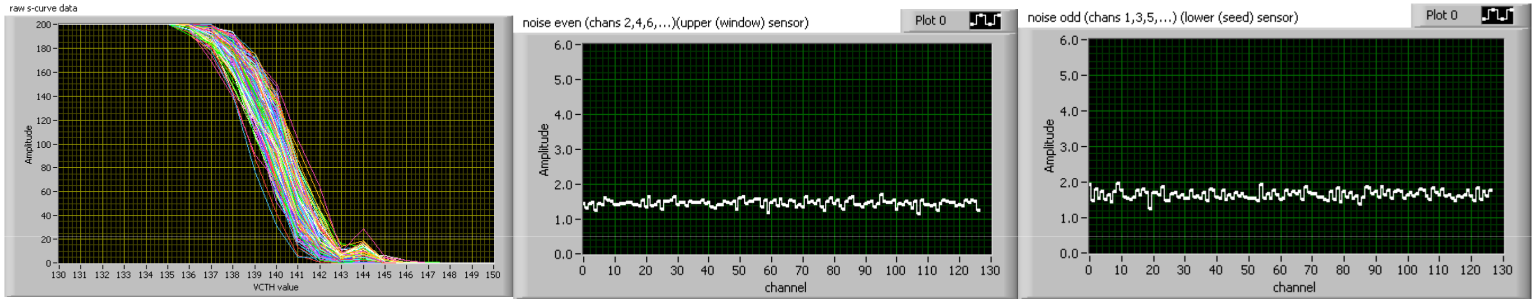
similar observations as for A0 on AEMTEC and Valtronic hybrids with stiffener

AEMTEC (without stiffener) D1

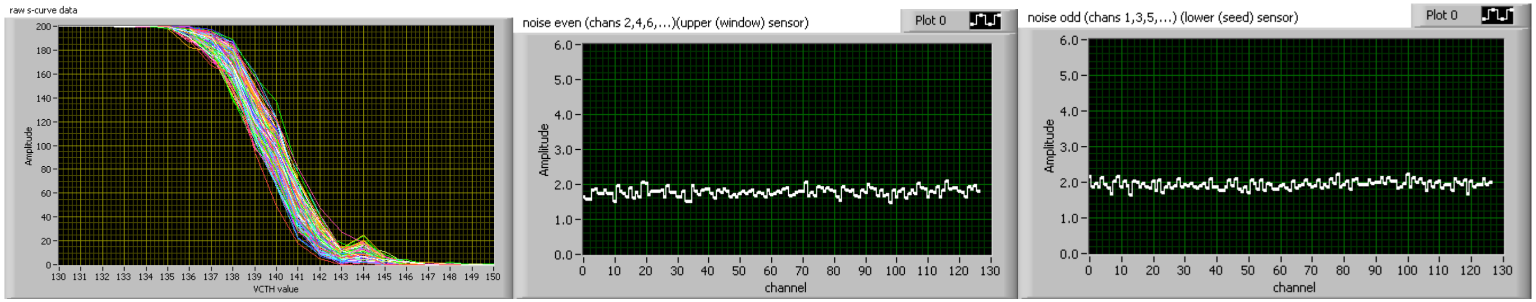




VPLUS selected
all channels
masked



VPLUS selected
all channels
unmasked



VPLUS unselected
all channels
unmasked

similar observations as for D1 on AEMTEC and Valtronic hybrids with stiffener

observations

so s-curve distortion effect linked to coupling between digital signals
and VPLUS (selected by AMUX) because they are routed adjacent on hybrid

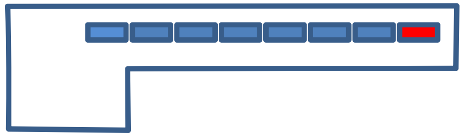
one of the lines is the trigger output line
(which is why unmasking the channels produces the effect)

explains why effect gets worse for chips furthest from power connector

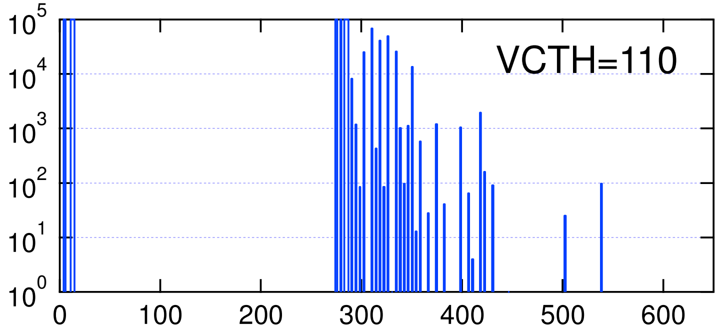
note that this effect is only present for CBC2 (because it helps with calibration
to use AMUX to select VPLUS and externally decouple)

what about "AMUX off" effect on double trigger effect?

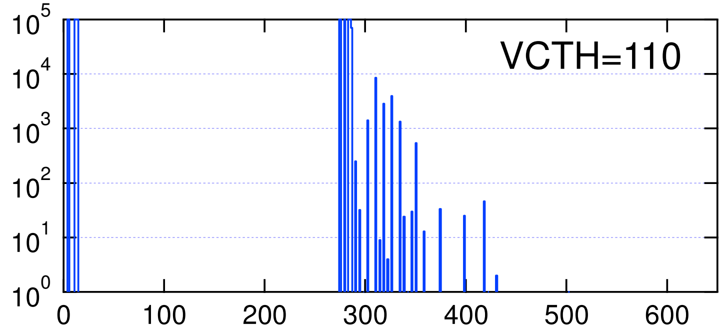
AEMTEC (with stiffener) A0



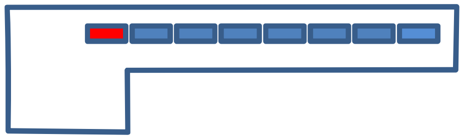
AMUX connected



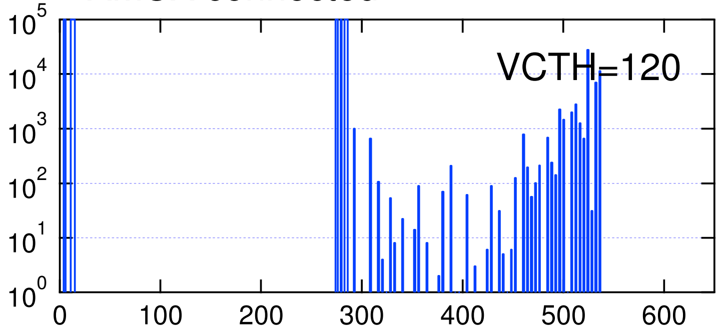
AMUX disconnected



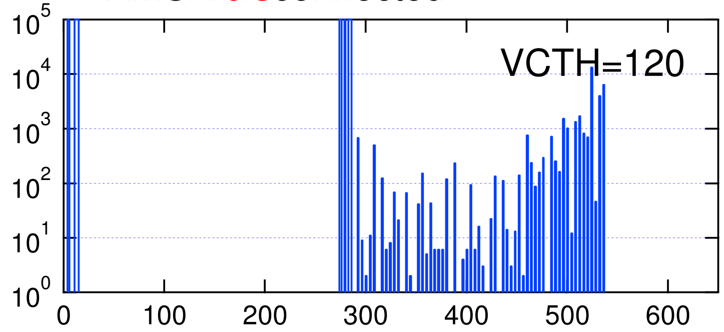
AEMTEC (with stiffener) D1



AMUX connected

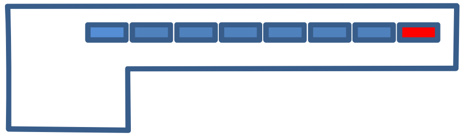


AMUX disconnected

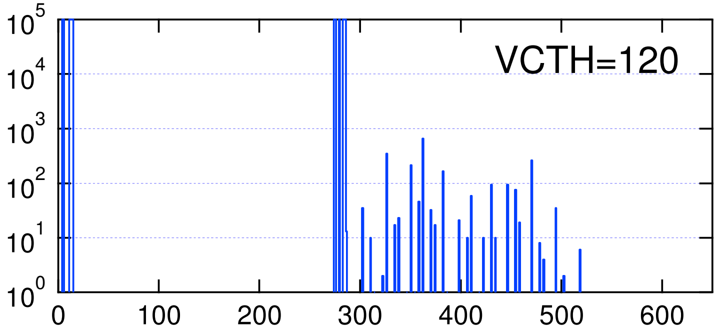


double trigger effect not dependent on AMUX connection

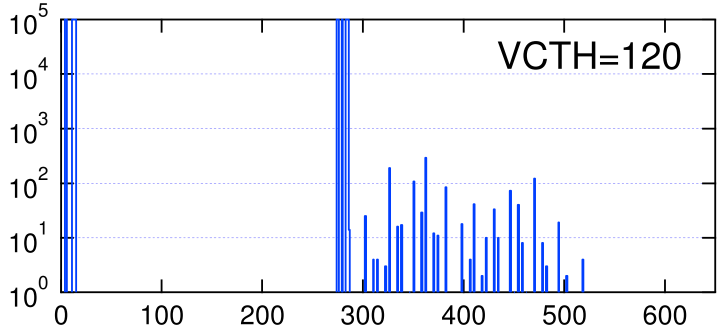
VALTRONIC (with stiffener) A0



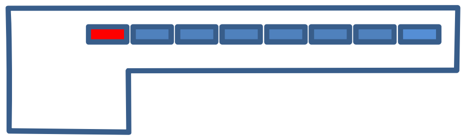
AMUX connected



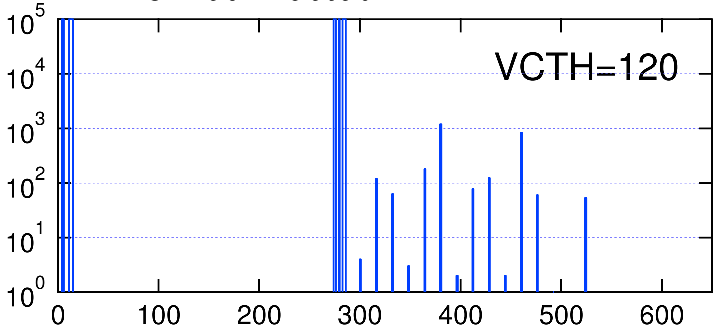
AMUX disconnected



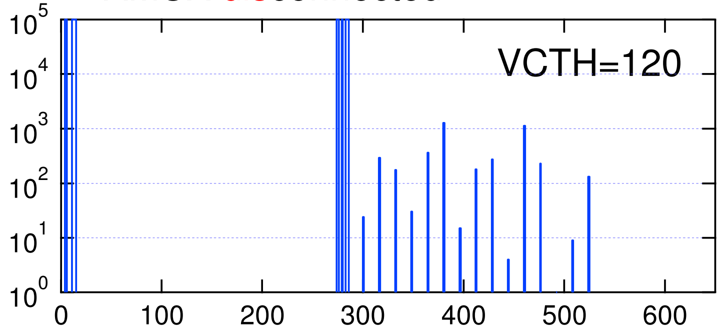
VALTRONIC (with stiffener) D1



AMUX connected

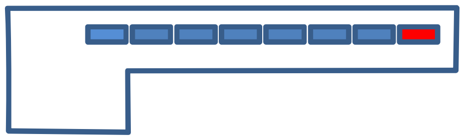


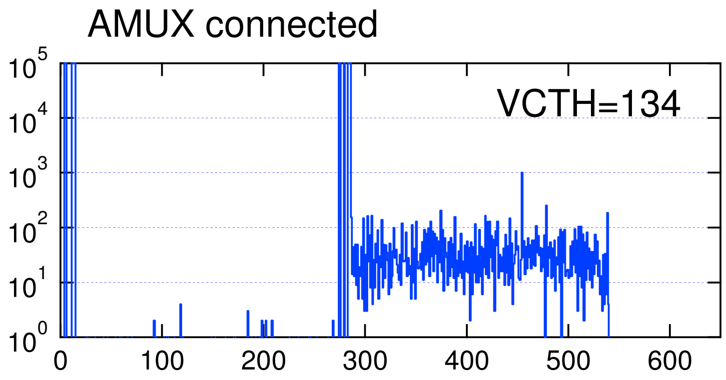
AMUX disconnected

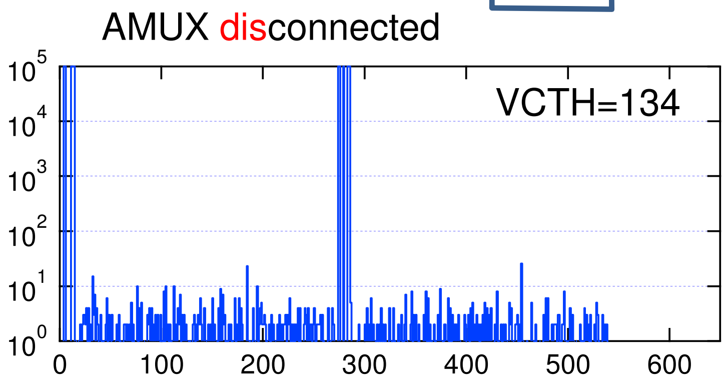


double trigger effect not dependent on AMUX connection

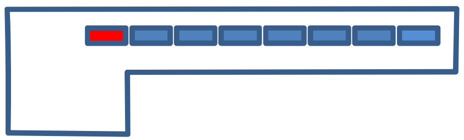
AEMTEC (no stiffener) A0

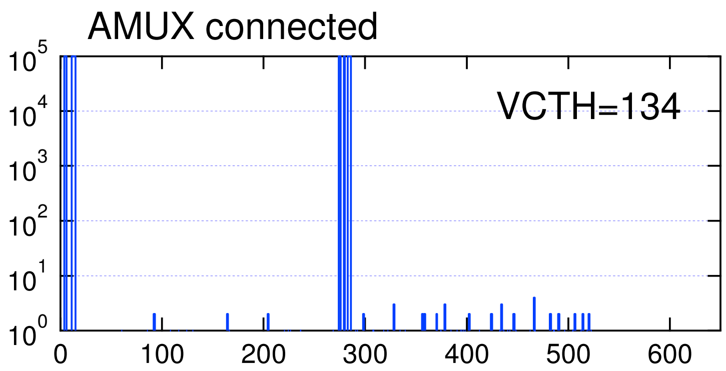


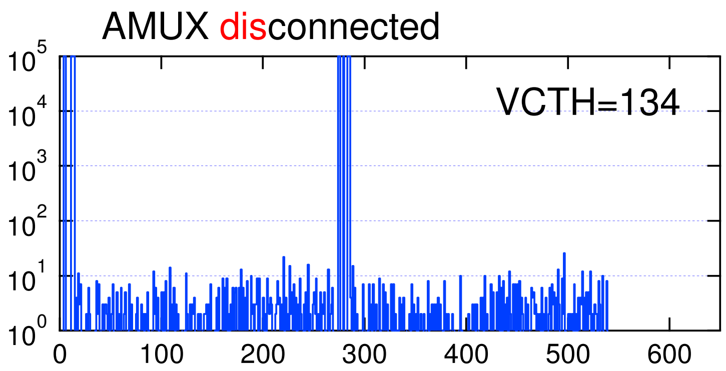




AEMTEC (no stiffener) D1







~small effect for chip A0 when no stiffener present

final remarks

there is some coupling between the two effects but:

s-curve distortion effect dominated by coupling between AMUX output (selecting VPLUS) and adjacently tracked digital signals

this effect should disappear for CBC3 (but worth avoiding anyway)

double trigger effect dominated by digital activity coupling into stiffener, and subsequently coupling back into chip inputs

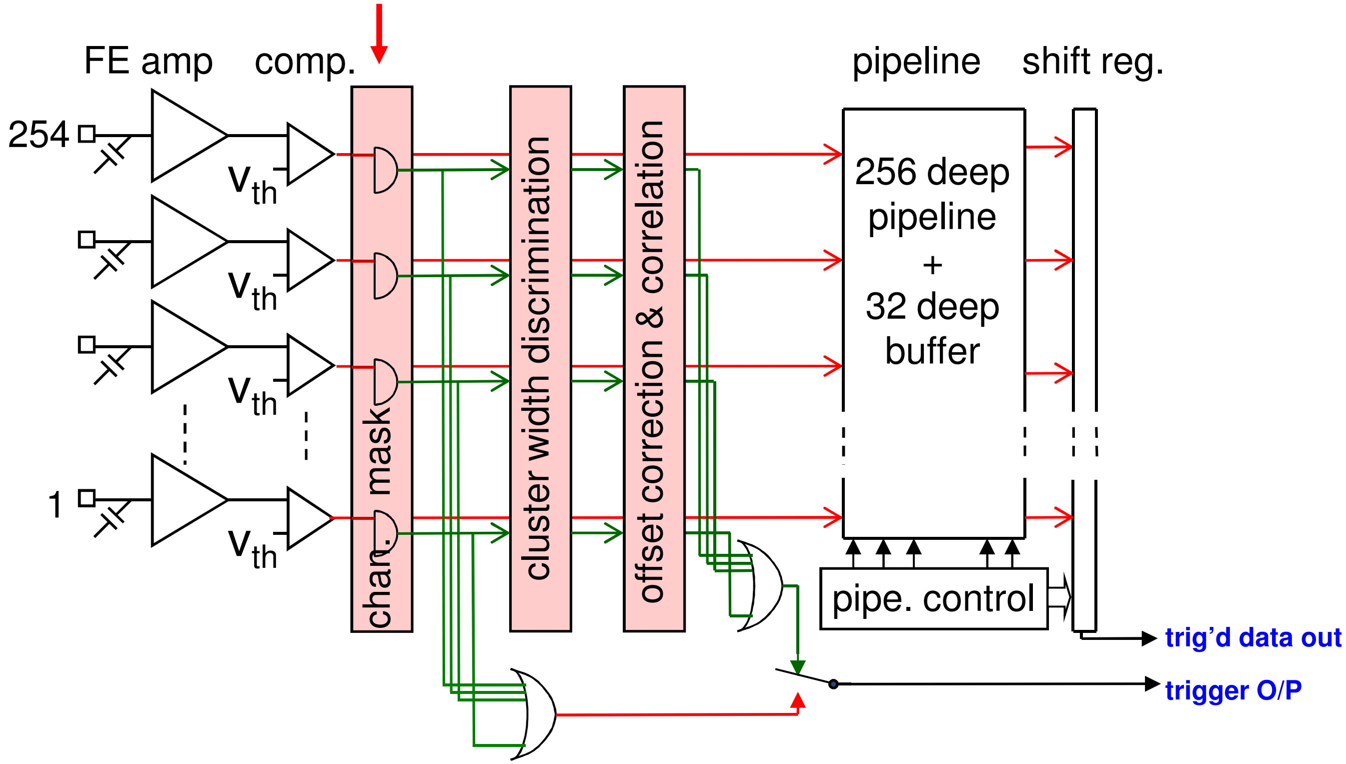
this effect can hopefully be eliminated by grounding stiffener

measurement conditions

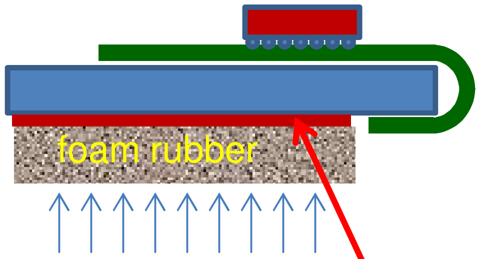
pedestals tuned to VCTH = 140 (decimal)

operation in electrons mode so **smaller** VCTH value => **higher** threshold

early on realised that observed s-curve effects depend on whether channels masked/unmasked from correlation logic

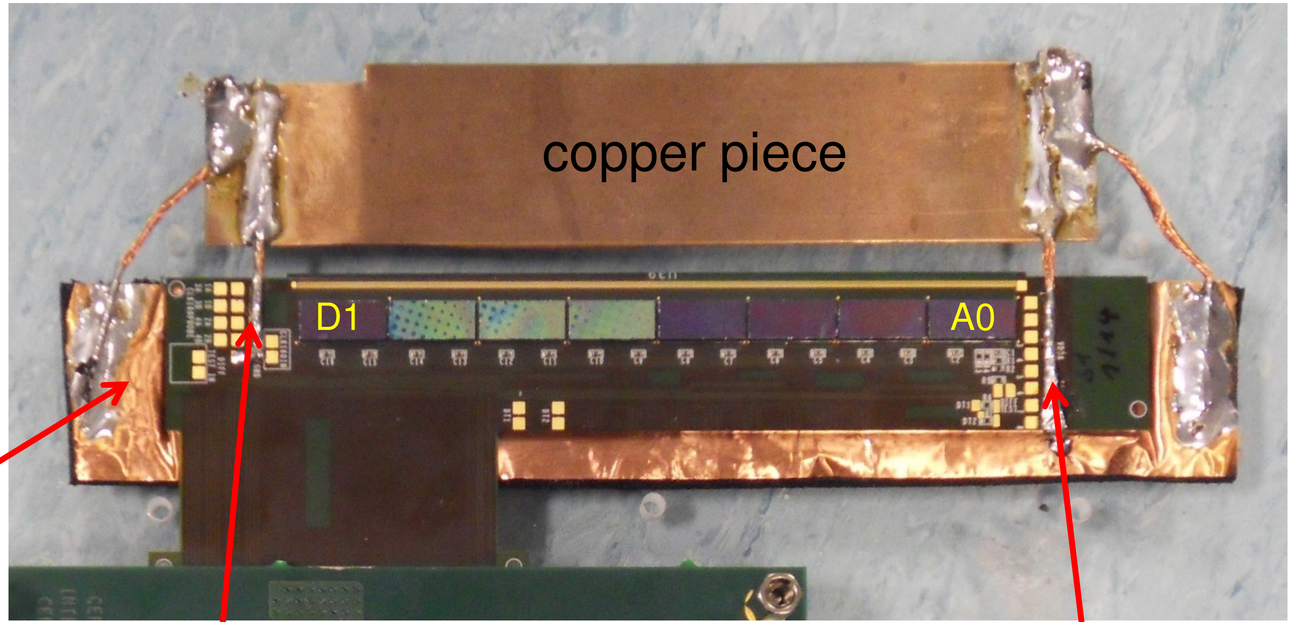


some attempts to improve ground for AEMTEC hybrid



pressure

grounded Cu foil



solder connection
to ground area
on hybrid

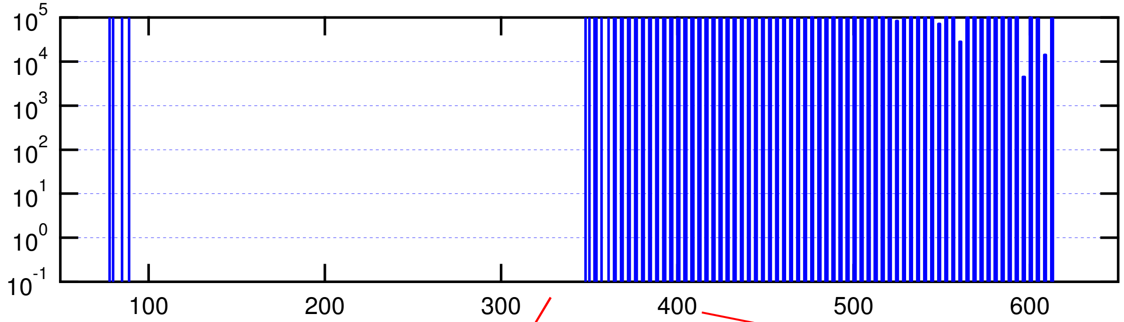
solder connection
to ground area
on hybrid

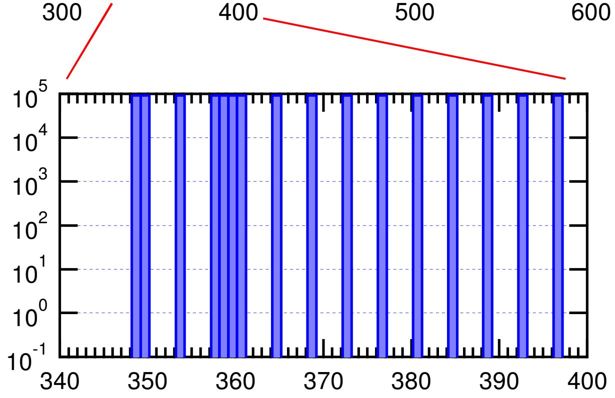
add low impedance connection between both ends of hybrid (copper piece)

add Cu foil to underside of hybrid, using electrically conductive grease to try and achieve grounding of carbon fibre stiffener

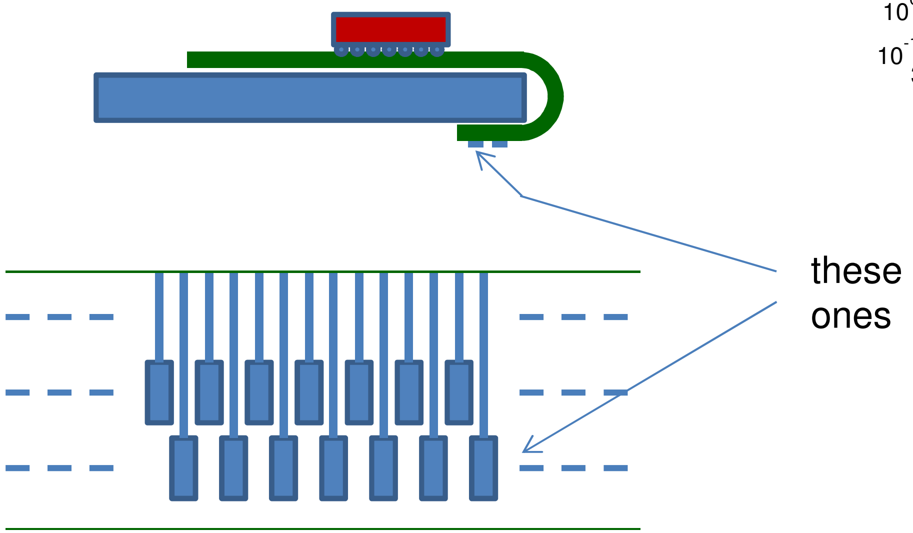
important observation

A0, no additional grounding, VCTH = 120





channels affected are every 4th , corresponding to farthest tracked channels on folded over region of flex hybrid



conclusions from last time

1st effect

get s-curve distortions for chips furthest from power supply end of AEMTEC hybrid when channels are <u>unmasked</u> from correlation logic

significant improvement if add grounding to CF stiffener

2nd effect

if trigger and read out chip at header time corresponding to a previous trigger see lots of channels firing

VCTH threshold has to be increased enormously before it goes away

but extra grounding almost eliminates effect for A0

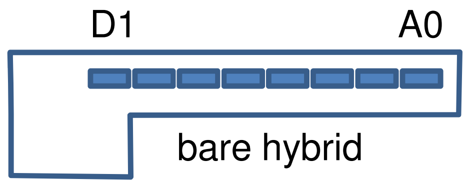
and completely eliminates for D1

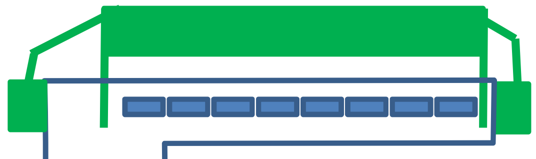
most effective is ground contact to back surface of stiffener

note: this effect does <u>not</u> require channels to be unmasked

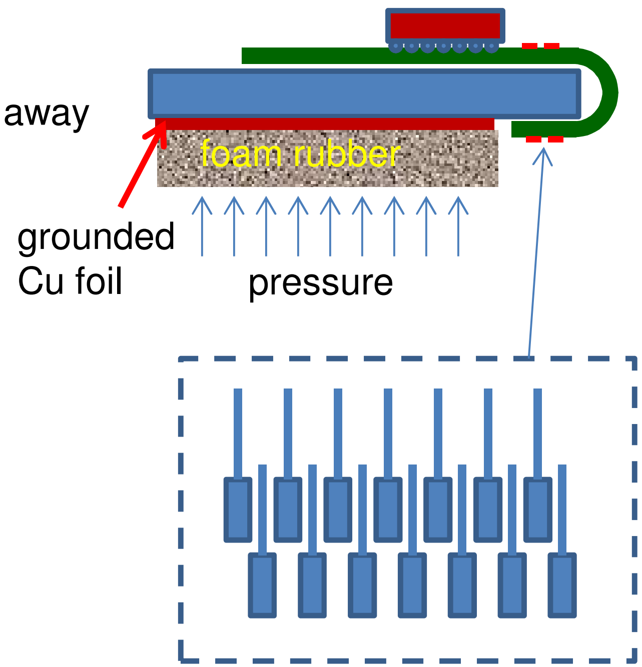
final significant point to note:

effect does <u>not</u> appear on 2CBC2 hybrid



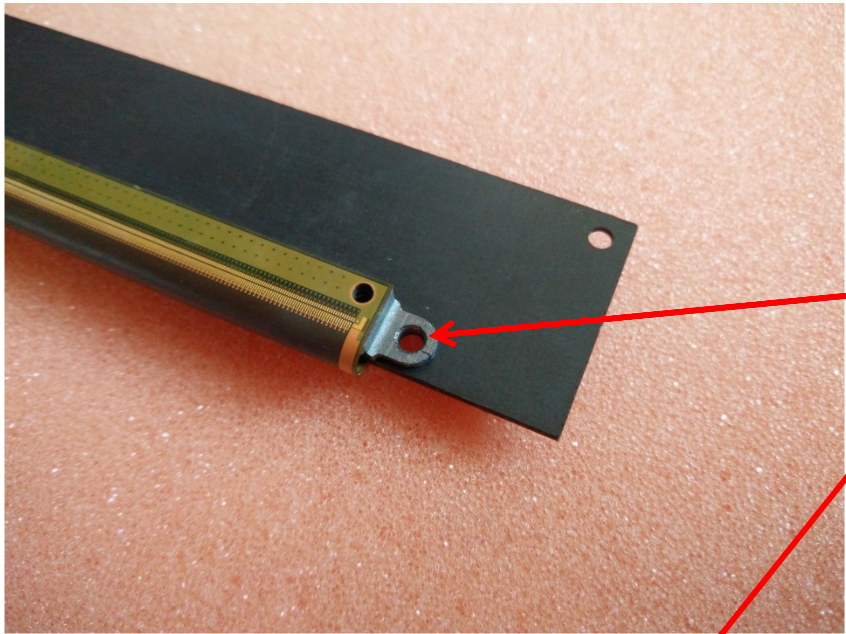


added ground path
and carbon support grounded



staggered pad pattern

Valtronic hybrid results

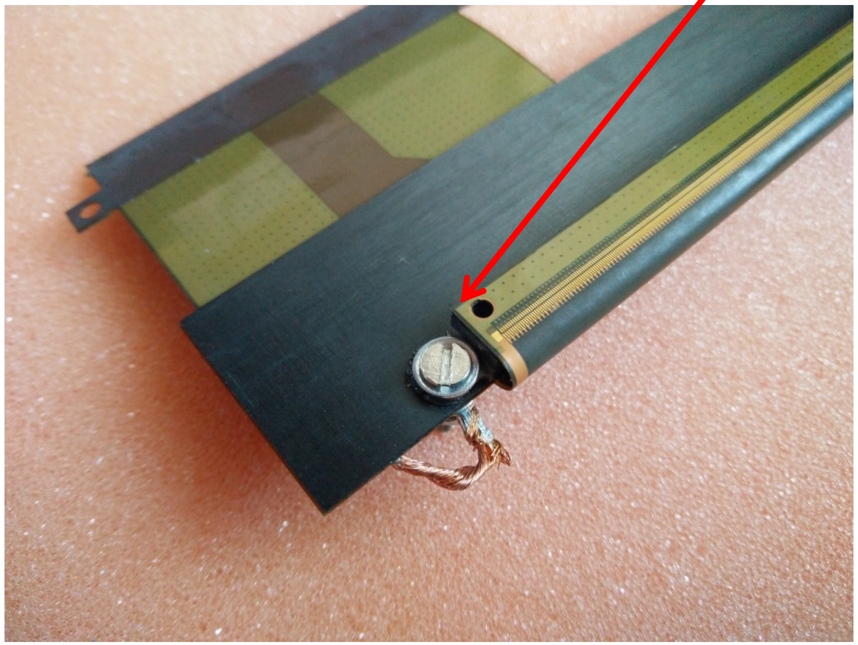


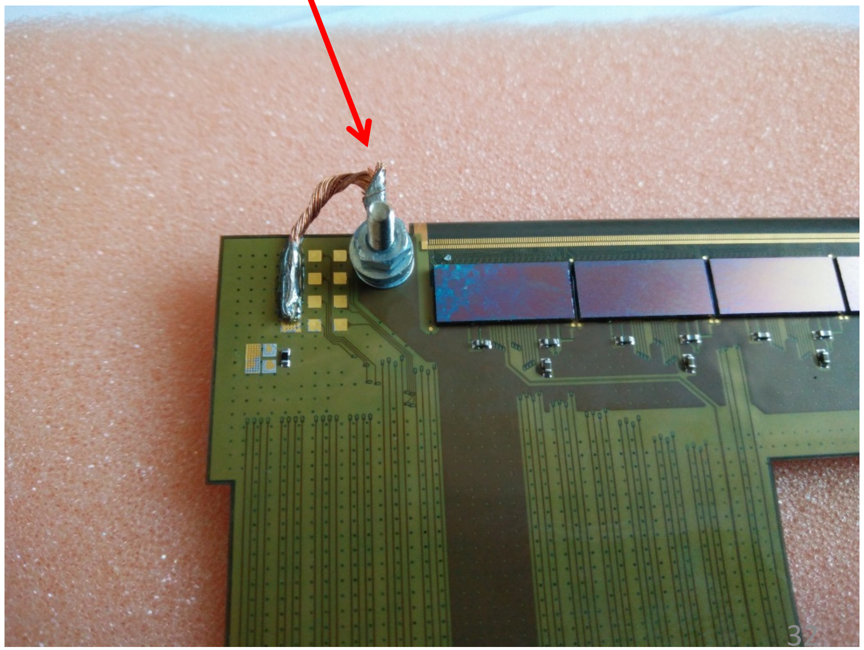
will compare bare hybrid performance with that obtained when ground contact made to carbon fibre piece that supports the foldover region of the hybrid

can make good electrical contact here

screw (+ washer) makes contact on underside of hybrid

solder tag connects screw to ground pad on hybrid (contact only made at one end only - the one nearest the power and signal cable)





back to s-curve distortions

After we had a meeting with Georges and Tomasz last week, I checked again the flex designs and I realized that I was wrong with the statement: More digital lines are exposed to the carbon fiber stiffener in the proximity of the A0 than in the proximity of the D1. Actually this is not true for the hybrids, because most of the exposed traces are evenly distributed. The peak area of exposed traces is in the proximity of CBC2 D0,C1 and C0 on both hybrids (Much less on the Valtronic all together). You can see it on the following screenshot made from the Valtronic design (Yellow is the layer closest to the CF, blue is the layer above the bc

And anyway, the noise coupled to the carbon fibre stiffener from these emissions should be evenly distributed to all chips by the CF stiffener if resonances does not occur (I think). So I started to look for something that has correlation with the distance from the connector. I found two things:
LDO_OUT -> routed to probe pads, it has negative correlation (trace length is the most for the D1), so I excluded this.
AMUX: This line is routed to the connector and its length grows proportionally with the distance. And here I realised a mistake from my side.
The AMUX out is routed together with the digital lines on both hybrids. Therefore it is well coupled to some of the digital logic outputs.
On the 8CBC2flex AEMtec the lines are coupling to:
CBC2 A0 AMUX is coupled to CBC2_A0_COIN_OR and CBC2_A0_COIN_DATA for approx. 8 cm length and the spacing is 50um. I expect around 3-4 % Xtalk.
CBC2 A1 AMUX is coupled to CBC2_A0_COIN_OR and CBC2_A0_COIN_DATA for approx. 7 cm length and the spacing is 50um. I expect around 3-4 % Xtalk.
CBC2 B0 AMUX is coupled to CBC2_A01_L1_TRIG and CBC2_B01_L1_TRIG for approx. 6 cm length and the spacing is 50um. I expect around 2-3 % Xtalk.
CBC2 B1 AMUX is coupled to CBC2_B1_COIN_OR and CBC2_B1_COIN_DATA for approx. 6 cm length and the spacing is 50um. I expect around 2-3 % Xtalk.
CBC2 C0 AMUX is coupled to CBC2_C0_COIN_OR and CBC2_C0_COIN_DATA for approx. 5 cm length and the spacing is 50um. I expect around 2-3 % Xtalk.
CBC2 C1 AMUX is coupled to CBC2_C0_COIN_OR and CBC2_C0_COIN_DATA for approx. 4 cm length and the spacing is 50um. I expect around 1-2 % Xtalk.
CBC2 D0 AMUX is coupled to CBC2_D0_COIN_OR and CBC2_D0_COIN_DATA for approx. 2 cm length and the spacing is 50um. I expect around 1 % Xtalk.
CBC2 D1 AMUX is coupled to CBC2_D1_COIN_OR and CBC2_D1_COIN_DATA for approx. 1 cm length and the spacing is 50um. I expect around 1 % Xtalk.
Example of AMUX routing of A0:

I think you are using the AEMtec 8CBC2flex hybrids with the AMUX set to output the Vplus in order to provide sufficient decoupling. The decoupling capacitor is placed on the interface board and therefore it is very far from the chip A0 and it serves as an antenna which is connected just into the analogue part of the CBC2. Could you confirm that you used the AMUX in this configuration during your measurements?
I checked also on the Valtronic hybrid, and the AMUX is routed similarly, always next to the Data output (stub shift register output) of the corresponding chip. The spacing here is 150um, and the decoupling is next to the CBC2 chips, therefore the effect is reduced, buy it is still there.

Could you try to measure the noise with the AMUX output turned off or connected to other voltage? It should eliminate the correlation with the distance if my theory is true.

It is still difficult to explain then why grounding the CF stiffener helps, but my theory is the following:
When the CF stiffener is not grounded, exposed traces are coupling noise into the CF and it emits this noise mainly into the longest sensor traces (Bottom sensor inputs) and everywhere.
In addition to that, the coupling from the AMUX increases the noise of each chip depending on the coupled length with the digital lines, causing the double trigger effect and further increasing the overall noise.

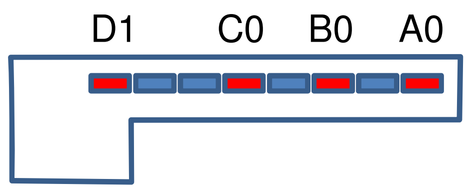
When you GND the CF stiffener, it eliminates the noise which is injected by itself, plus reduces the impedance of the exposed traces, therefore reduces the amount of Xtalk between the traces.
Probably it also serves as decoupling capacitor for each analogue input channel and it decreases the noise coupled by the AMUX by filtering the noise at the inputs.
I am not sure about understanding most of the effects, especially the dramatic effect of grounding the CF stiffeners, so probably it is not the full picture what I see there.

I hope it will help to understand the problems.

Counter acts:
For the new production of the 8CBC2flex, I will place the AMUX decoupling capacitor on the Hybrid (as on the Valtronic proto.) and I will not route the AMUX out to the interface board or have it connected with a jumper. The routing will be isolated from the digital lines.
I will place different values of decoupling capacitors on the hybrid, some larger at the input of the power and some smaller in the proximity of the chips.
I will shield all the exposed traces (if possible) next to the carbon fiber stiffener.
I am thinking about placing GND guard traces between every channel trace on the bottom. This would shield the inner traces and it would reduce the pickup in the bottom channels. But it would increase t he stray capacitance a little bit. Also the shielding can be upgraded by placing a meshed plane on the top, but it would make the folding a bit more difficult.

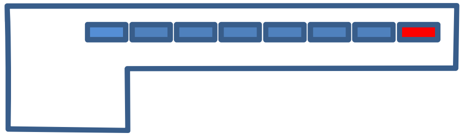
Thank you for reading my e-book.
Please let me know your opinion about this theory.

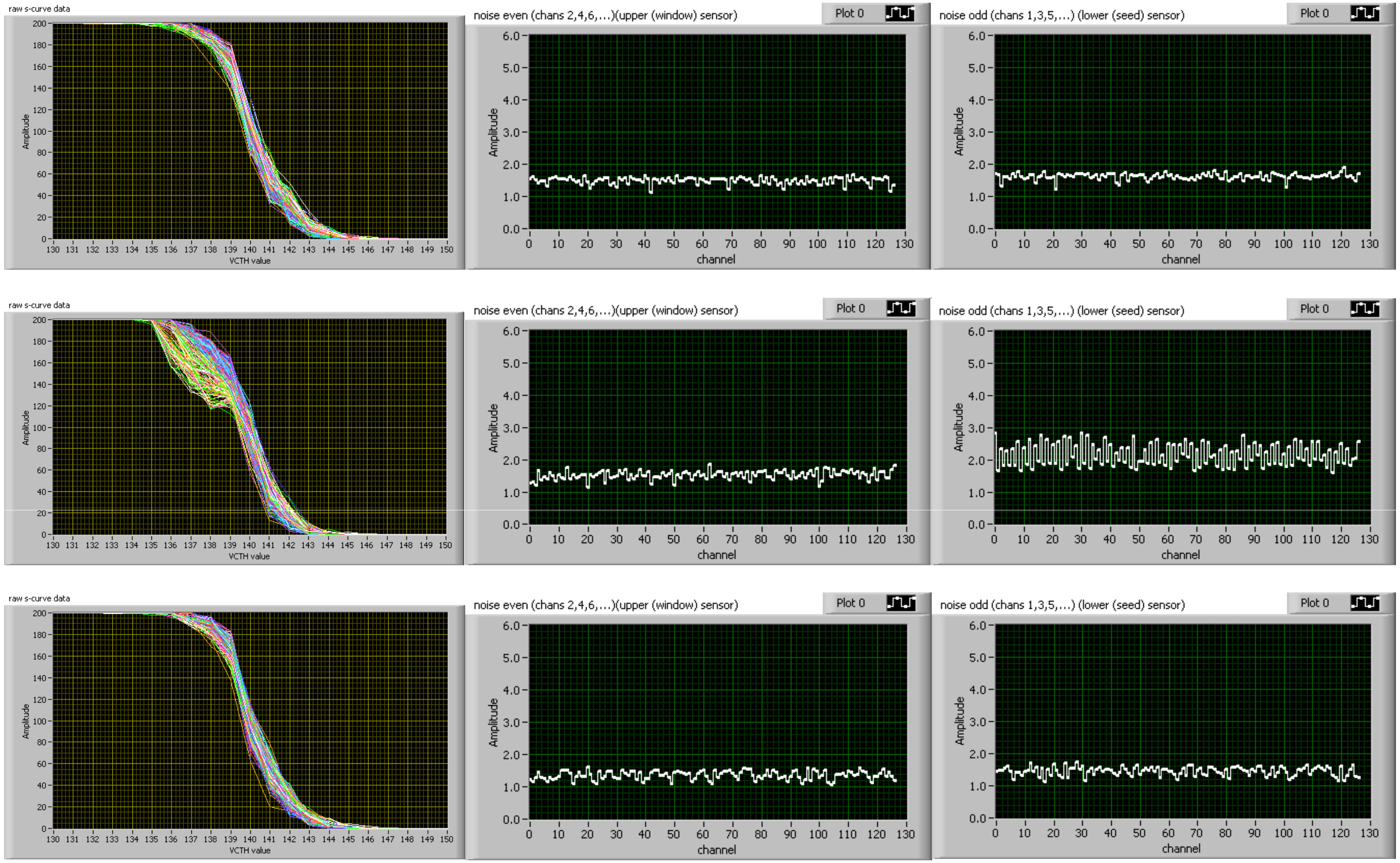
Cheers,



following 12 slides show detailed results of s-curve distortion measurements for all 3 hybrids for chips A0, B0, C0 and D1

AEMTEC with stiffener: A0



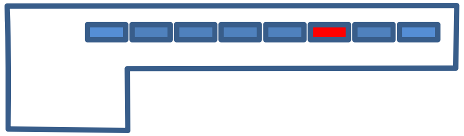


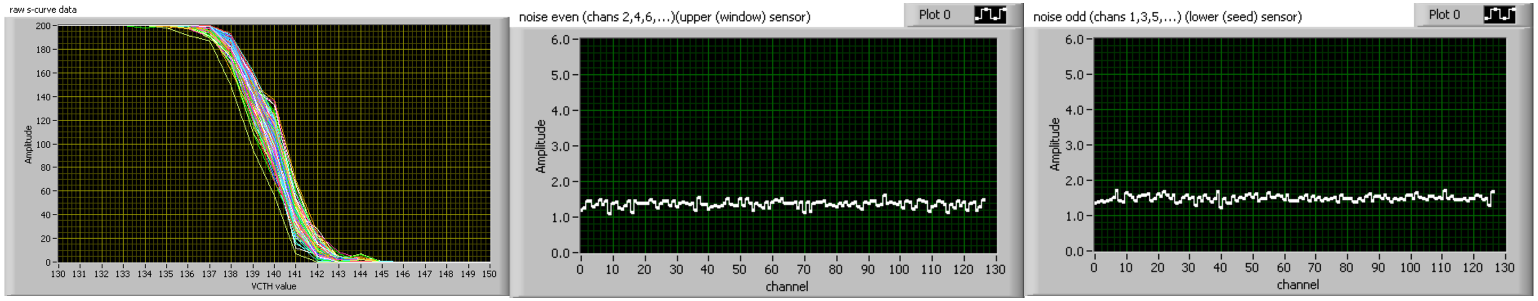
VPLUS selected
all channels
masked

VPLUS selected
all channels
unmasked

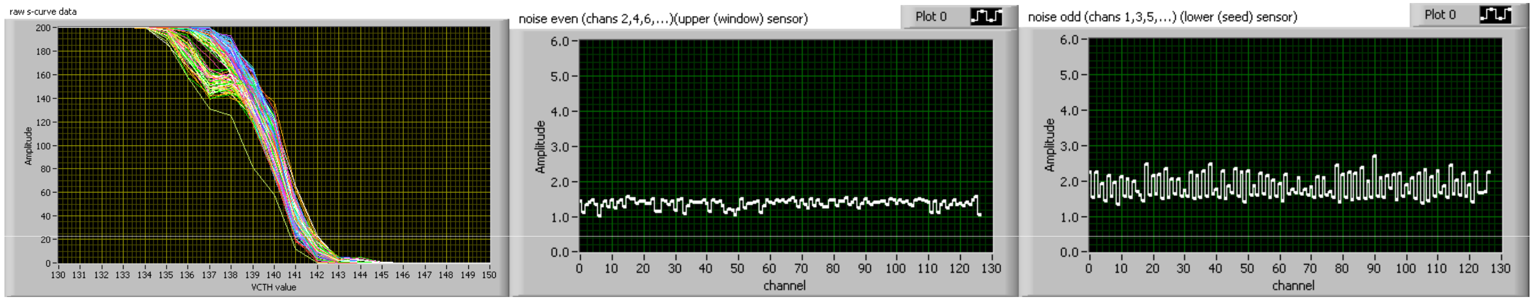
VPLUS unselected
all channels
unmasked

AEMTEC with stiffener: B0

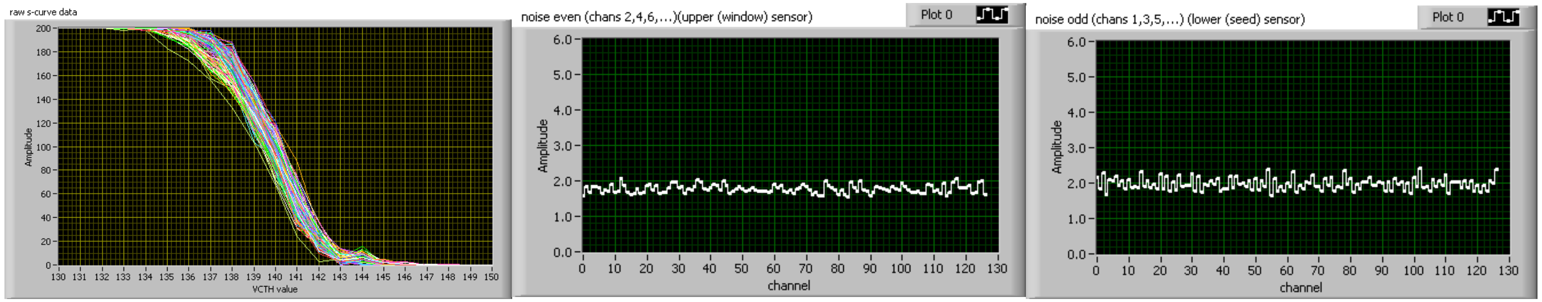




VPLUS selected
all channels
masked

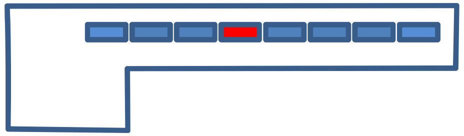


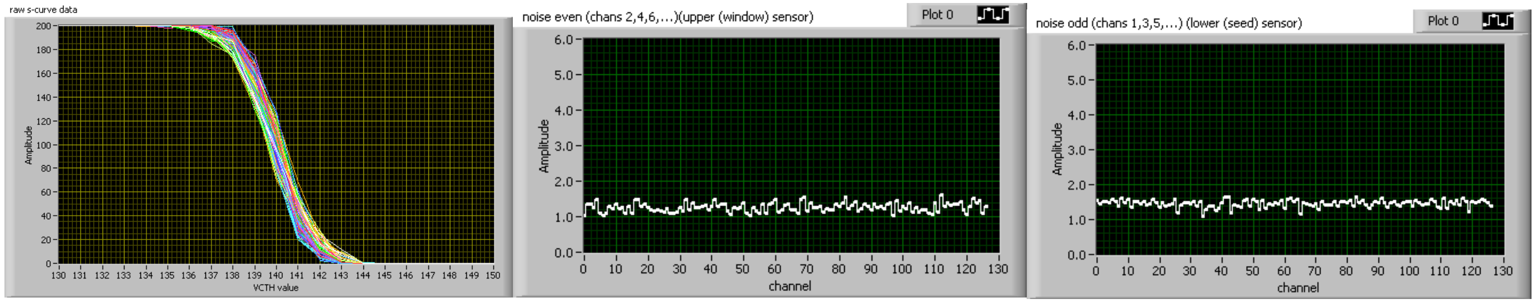
VPLUS selected
all channels
unmasked



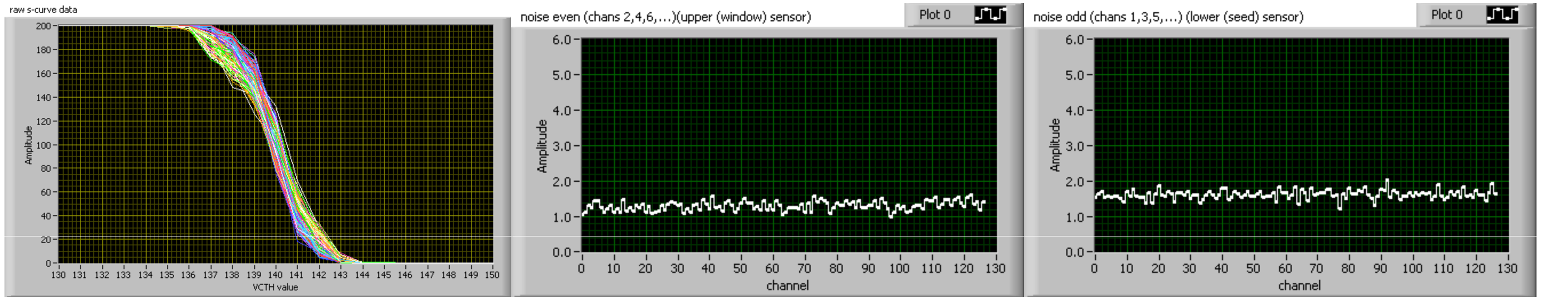
VPLUS unselected
all channels
unmasked

AEMTEC with stiffener: C0

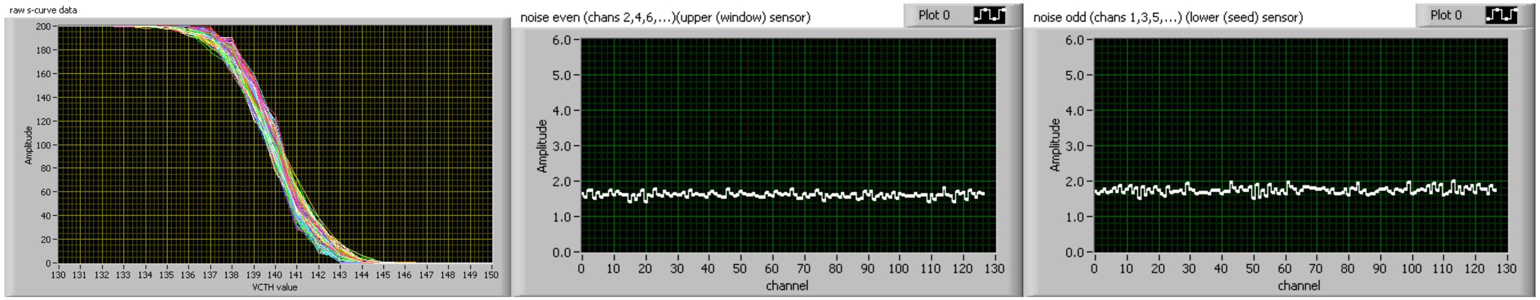




VPLUS selected
all channels
masked

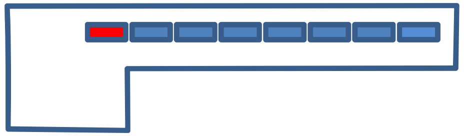


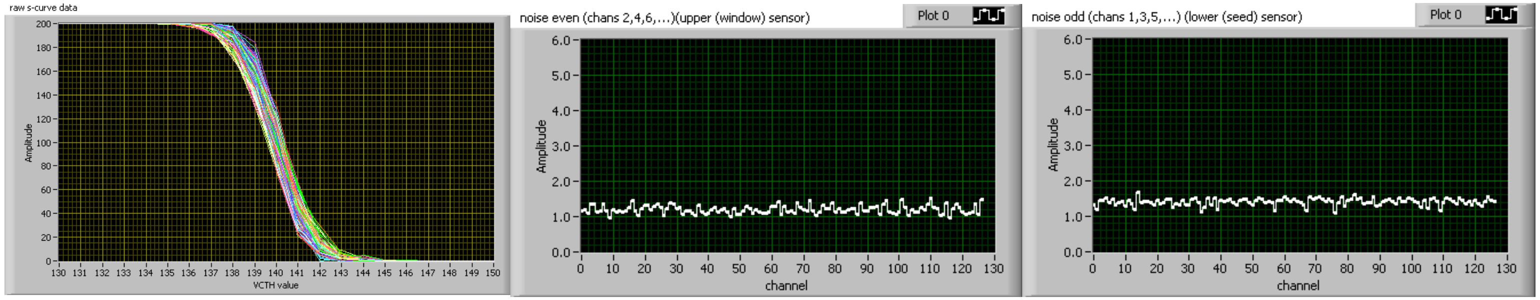
VPLUS selected
all channels
unmasked



VPLUS unselected
all channels
unmasked

AEMTEC with stiffener: D1





VPLUS selected
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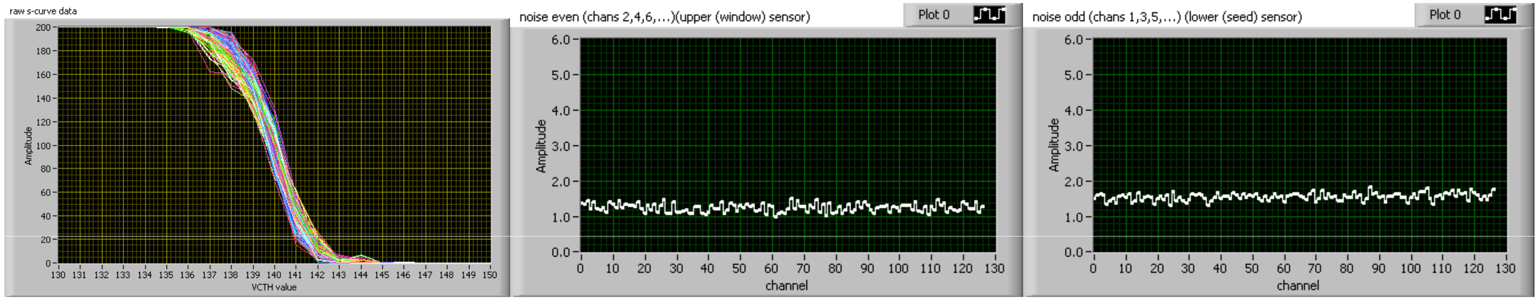
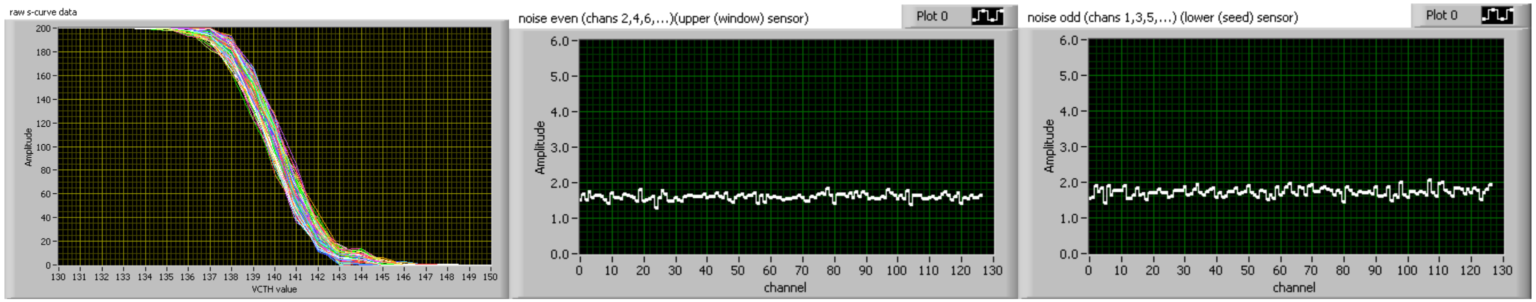
masked

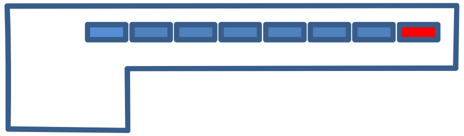


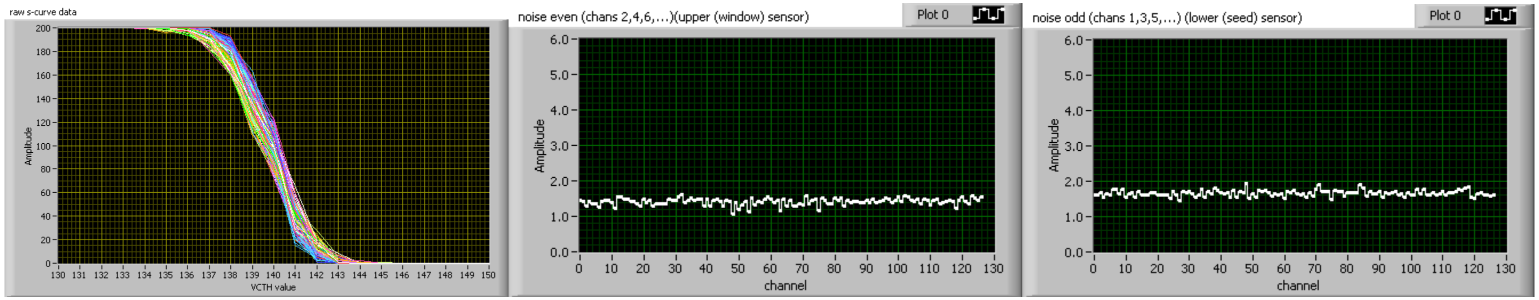
VPLUS selected
all channels
unmasked



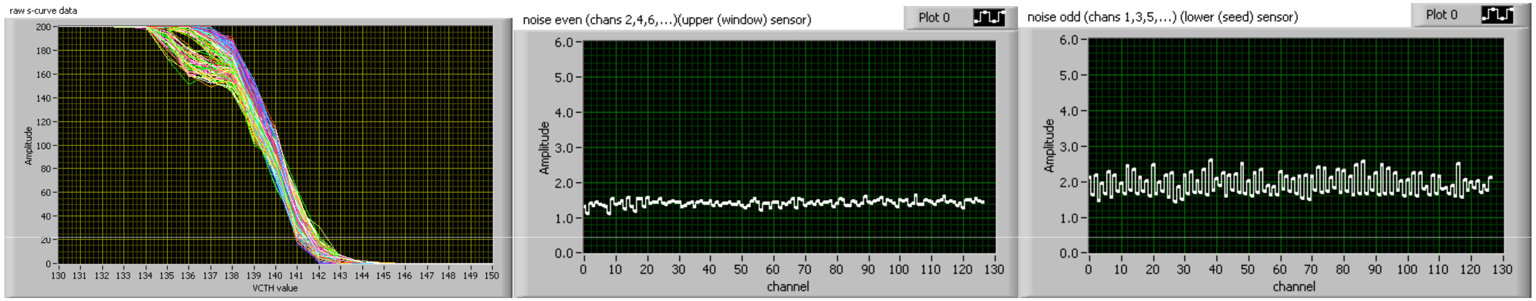
VPLUS unselected
all channels
unmasked

VALTRONIC (with stiffener) A0

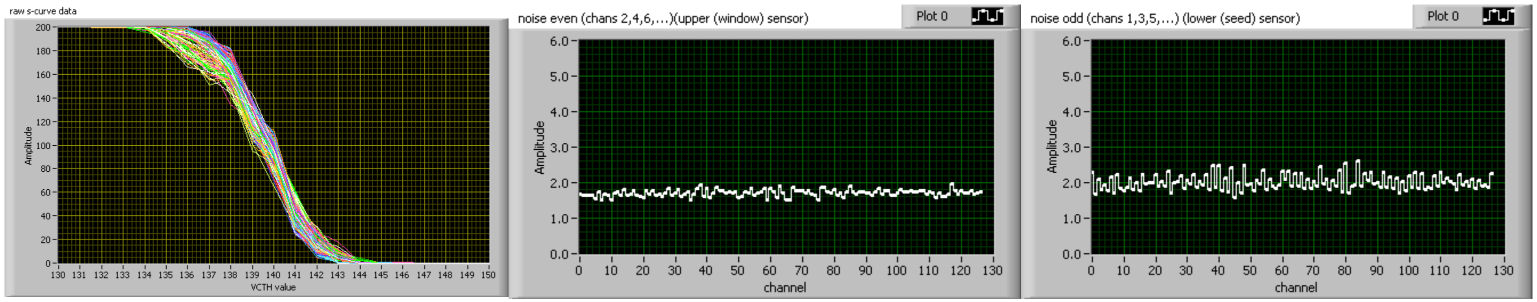




VPLUS selected
all channels
masked

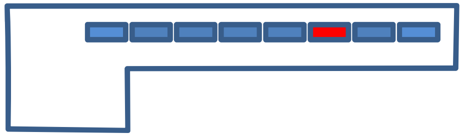


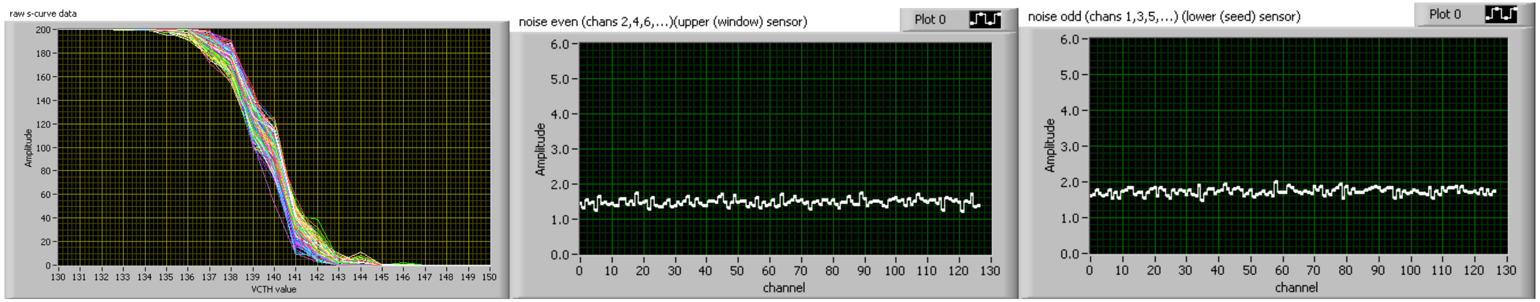
VPLUS selected
all channels
unmasked



VPLUS unselected
all channels
unmasked

VALTRONIC (with stiffener) B0





VPLUS selected
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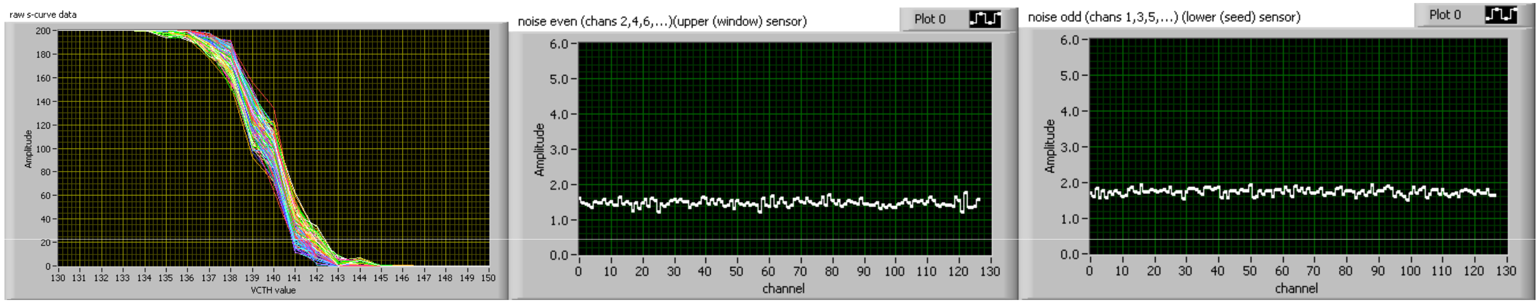
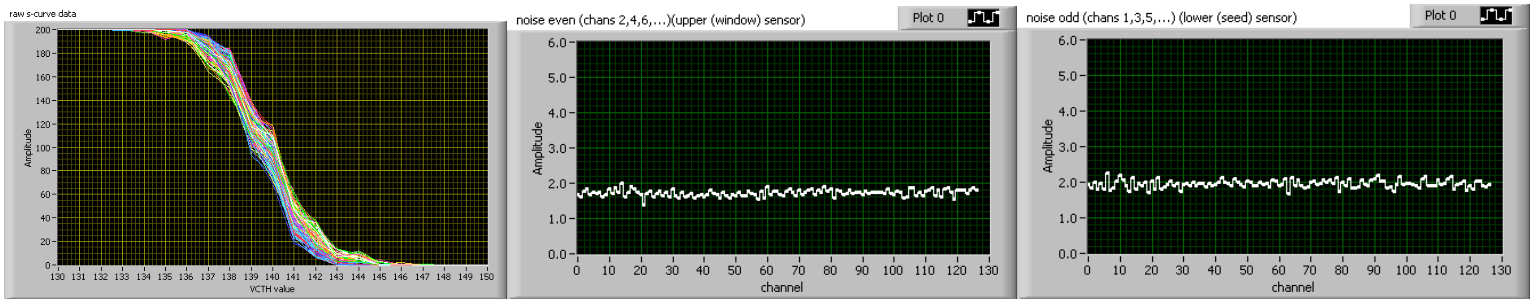
masked

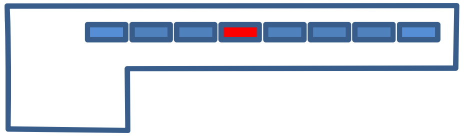


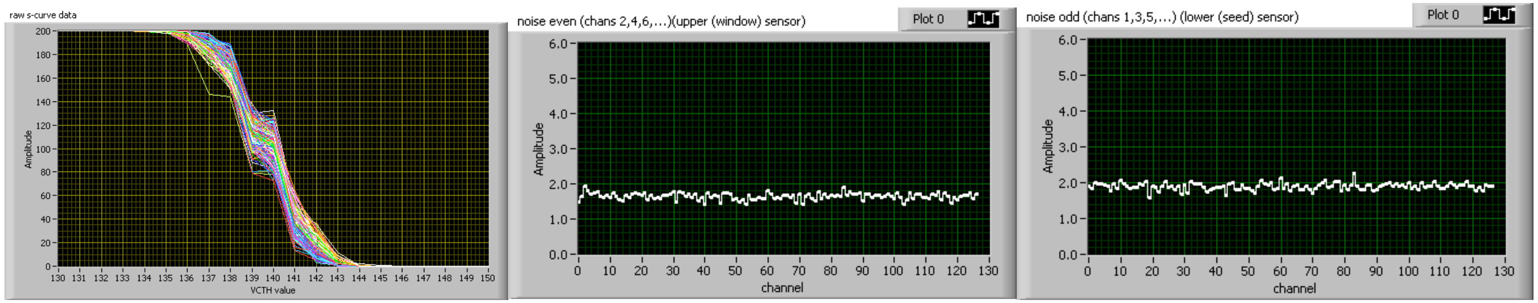
VPLUS selected
all channels
unmasked



VPLUS unselected
all channels
unmasked

VALTRONIC (with stiffener) C0





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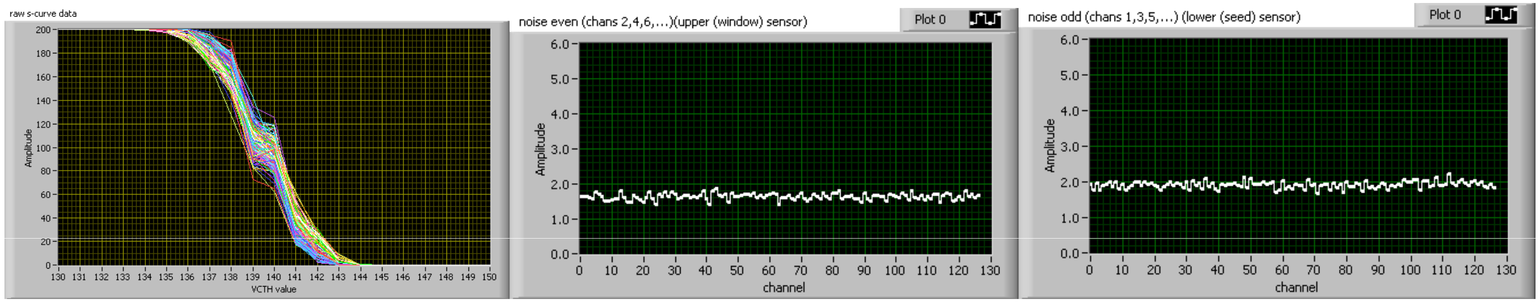
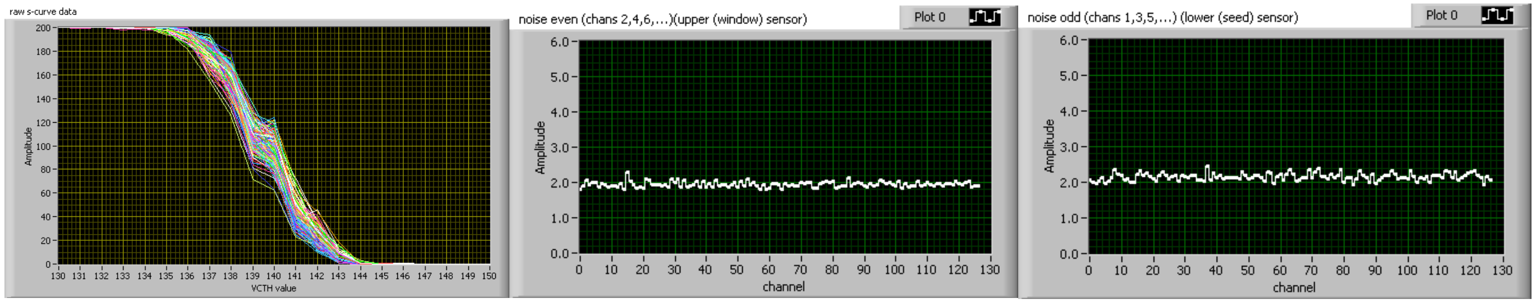
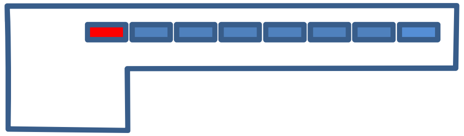


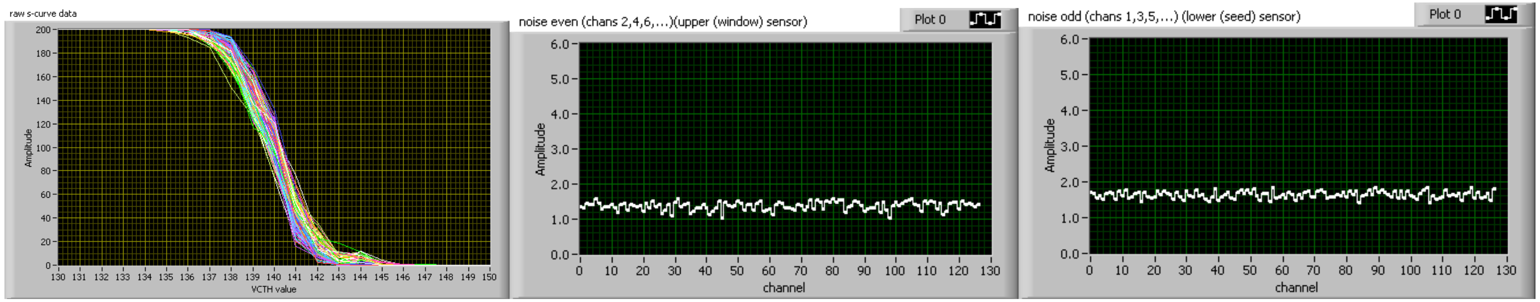
VPLUS selected
all channels
unmasked



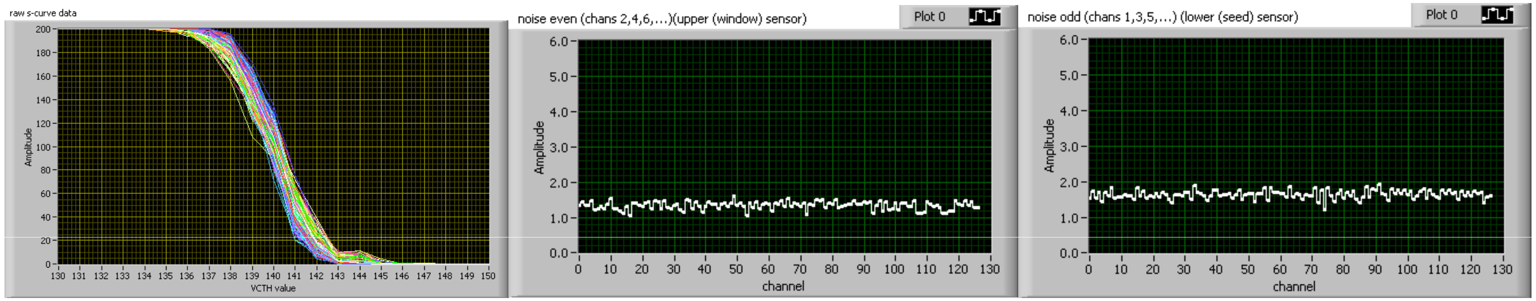
VPLUS unselected
all channels
unmasked

VALTRONIC (with stiffener) D1

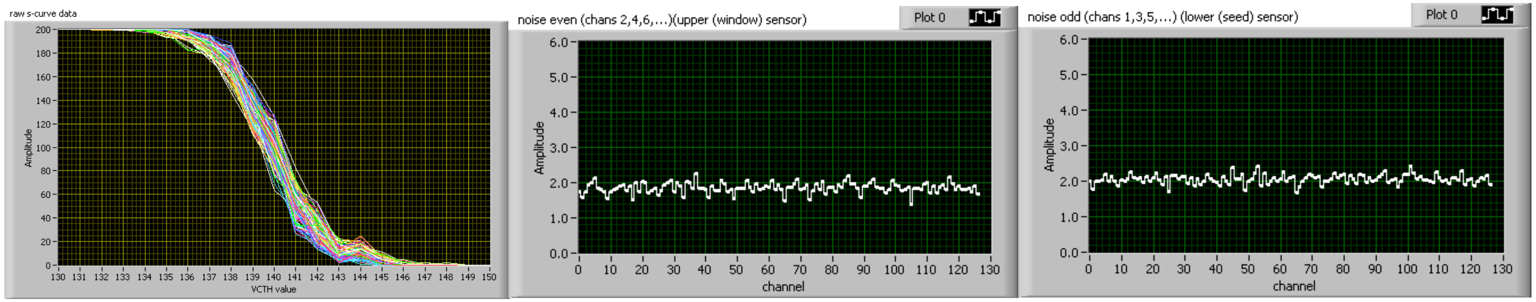




VPLUS selected
all channels
masked

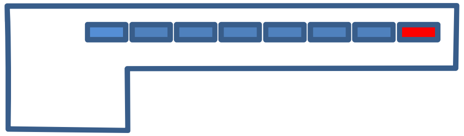


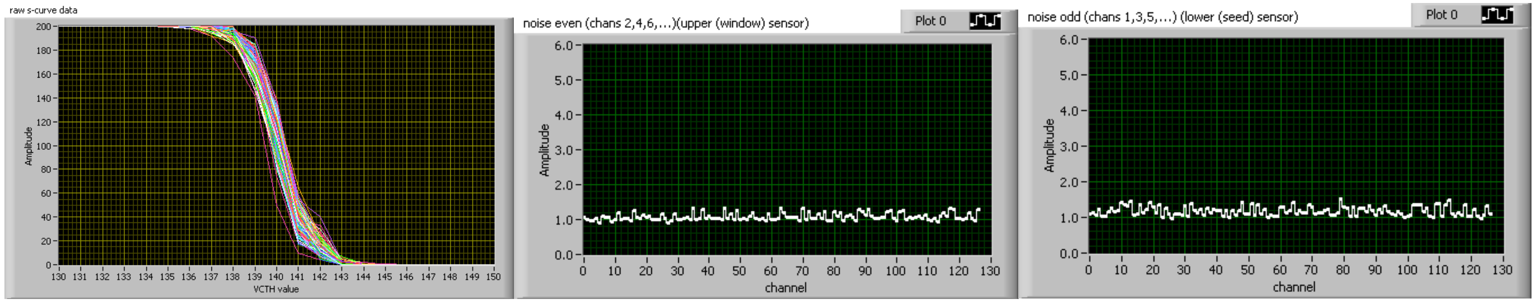
VPLUS selected
all channels
unmasked



VPLUS unselected
all channels
unmasked

AEMTEC (without stiffener) A0





VPLUS selected
all channels
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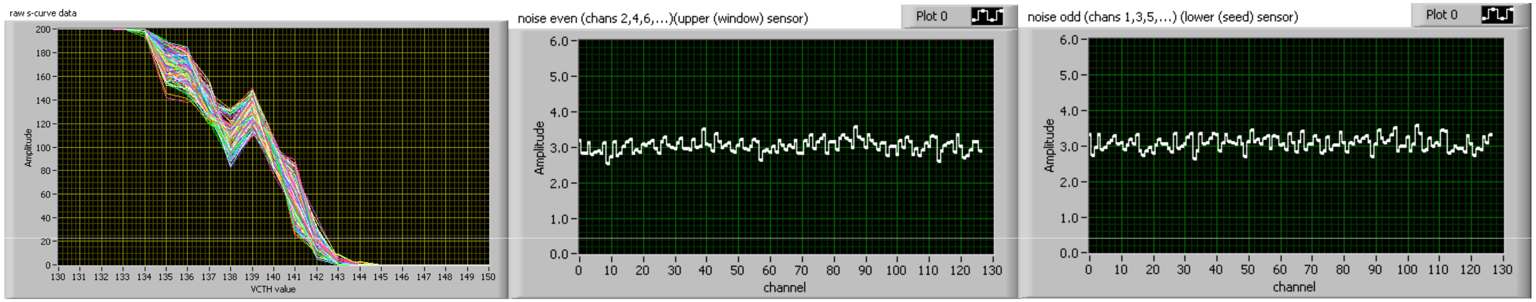

VPLUS selected
all channels
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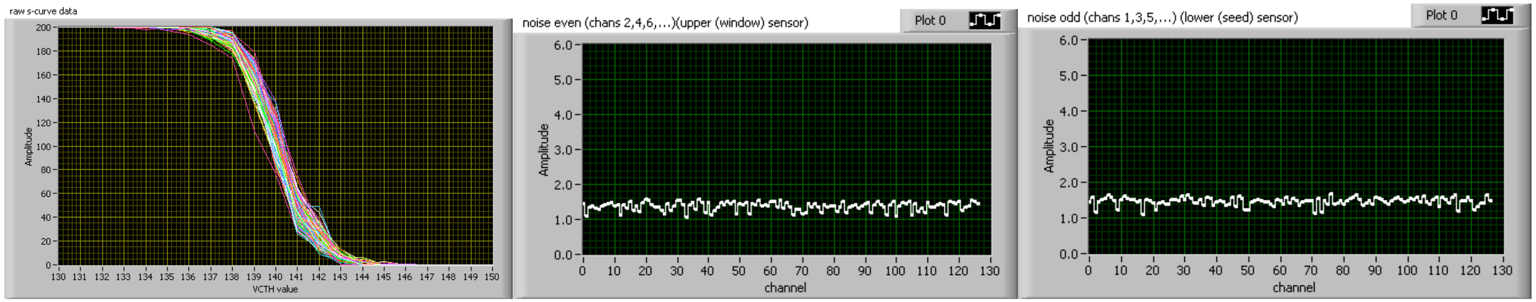
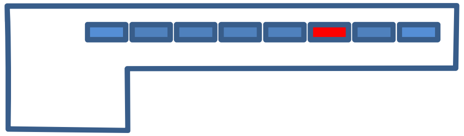
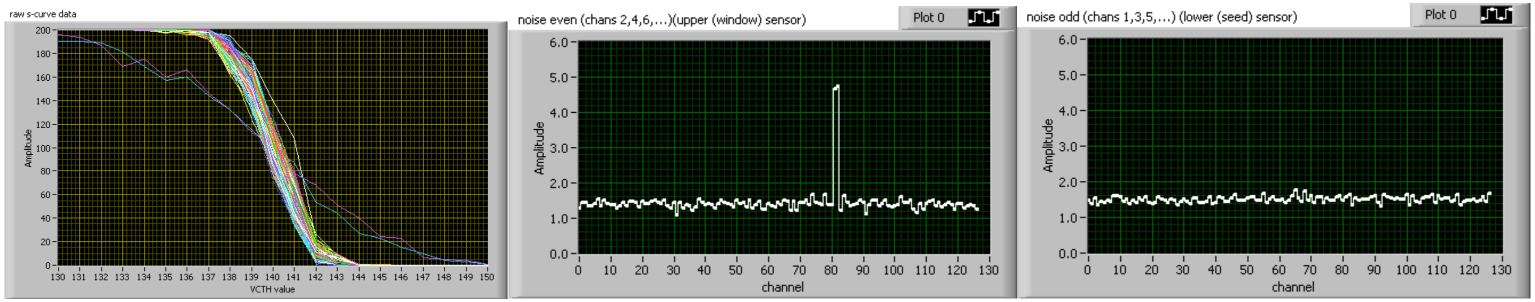


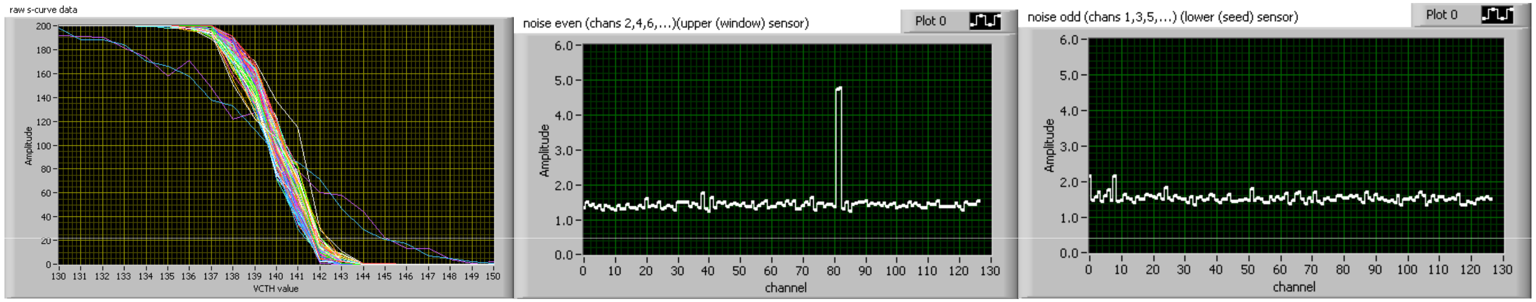
VPLUS unselected
all channels
unmasked

AEMTEC (without stiffener) B0

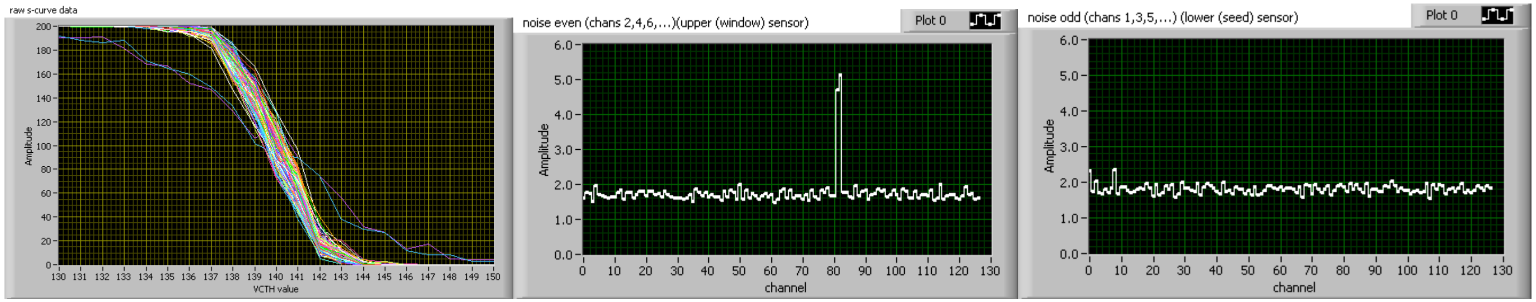




VPLUS selected
all channels
masked

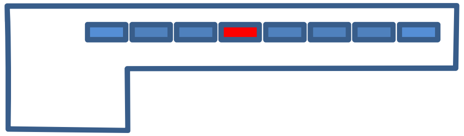


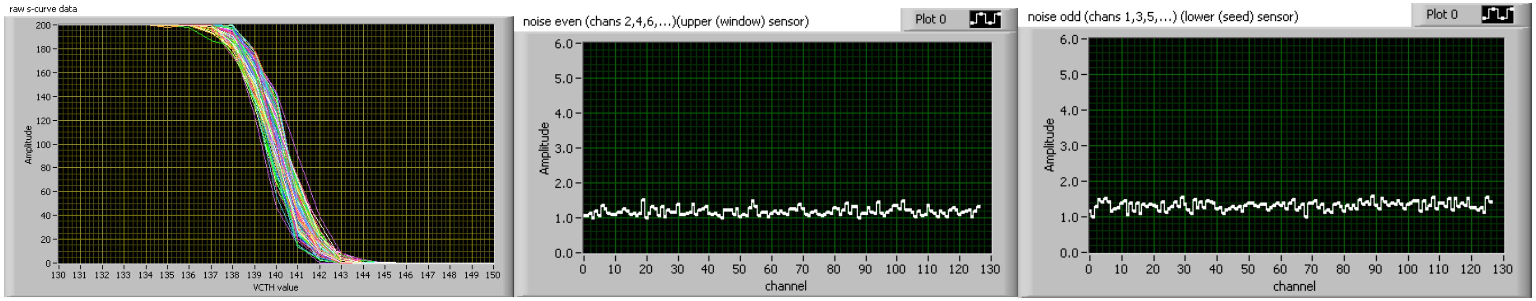
VPLUS selected
all channels
unmasked



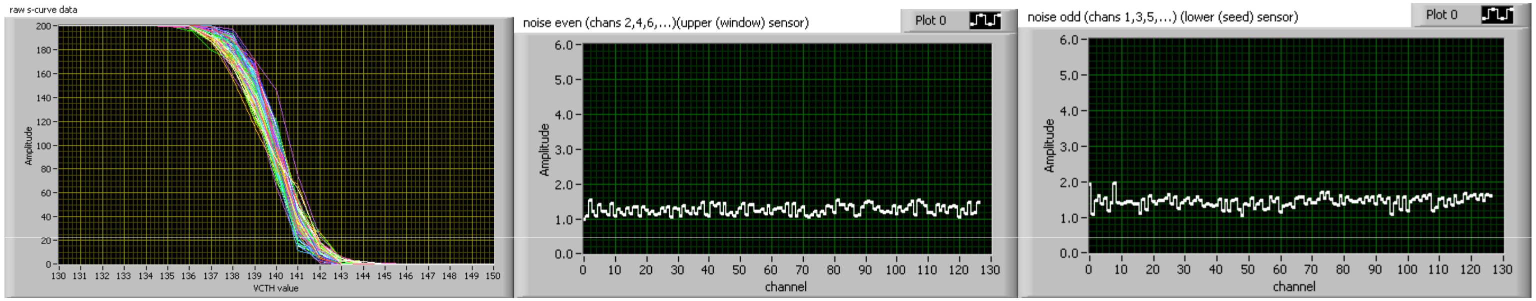
VPLUS unselected
all channels
unmasked

AEMTEC (without stiffener) C0

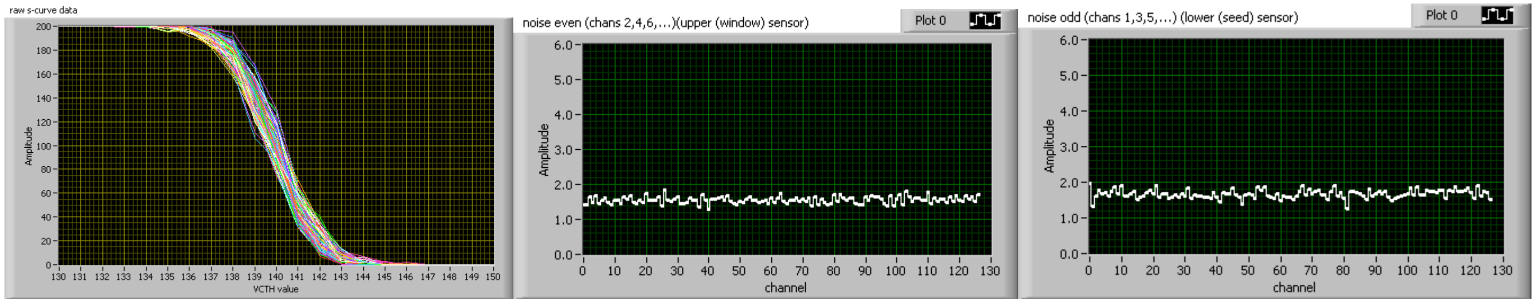




VPLUS selected
all channels
masked

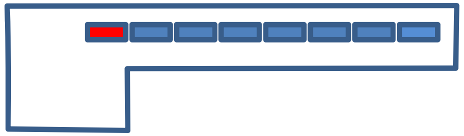


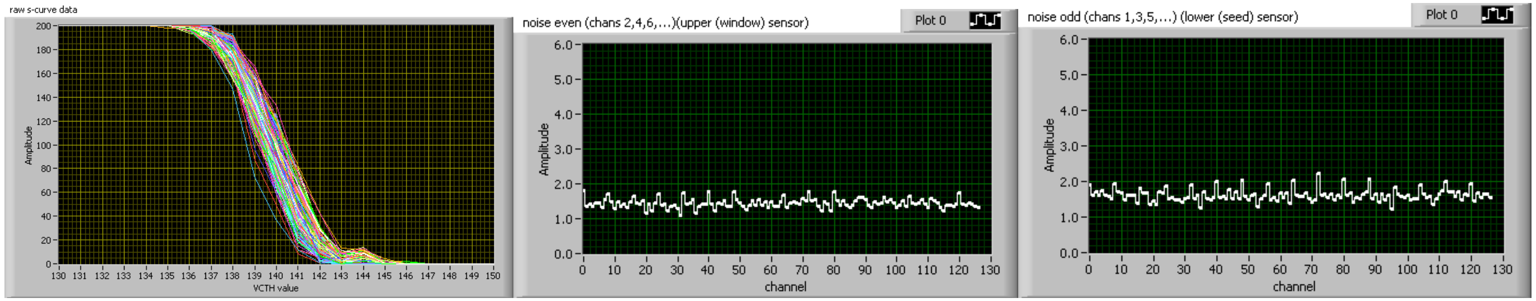
VPLUS selected
all channels
unmasked



VPLUS unselected
all channels
unmasked

AEMTEC (without stiffener) D1





VPLUS selected
all channels
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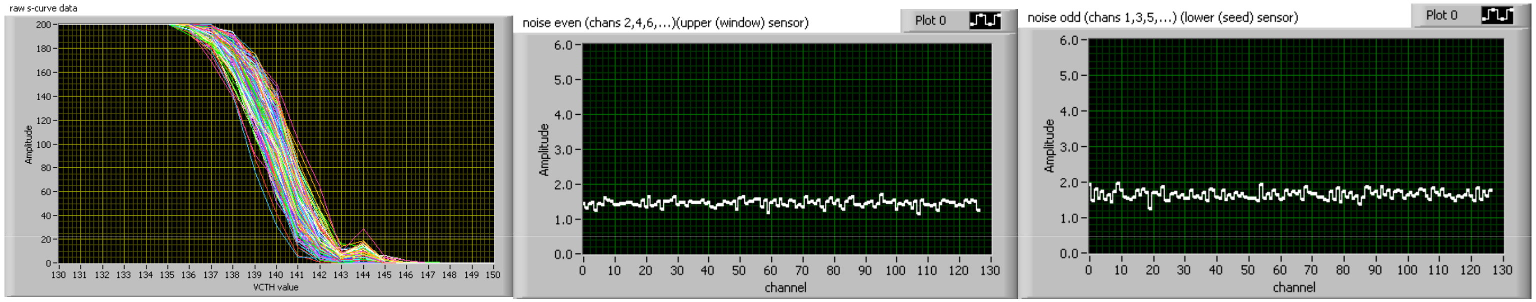
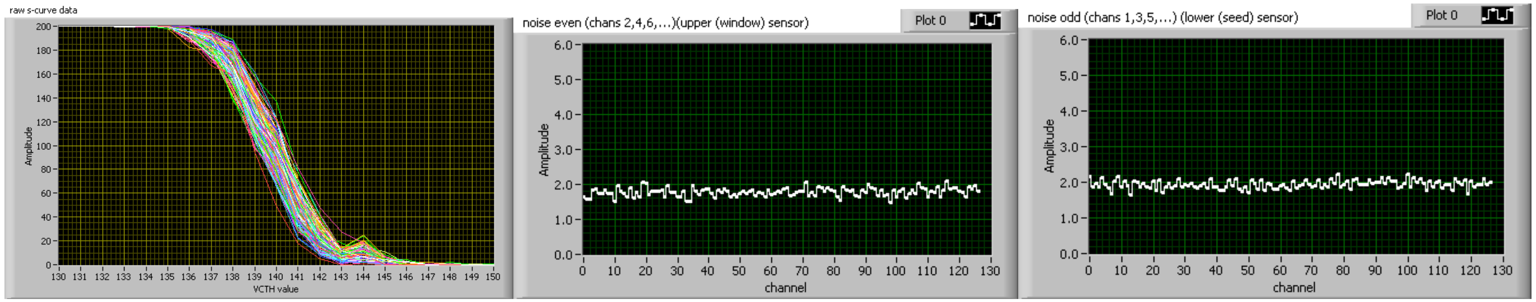


VPLUS selected
all channels
unmasked



VPLUS unselected
all channels
unmasked