Status of SC-DD FE Electronics for MIPs Timing

Andrei Caragheorgheopol

for

GSI – Darmstadt Group
and
NIPNE- Bucharest Group
of
NoRHDia Project

NoRHDia3 Workshop
GSI, 30.08-01.09.2006

Table of contents

Measurements

Focus on noise and rise time!

About setup

PULSE GENERATOR: 9210+9214/LeCroy

- U_{GEN}=±(500 → 5000mV)
- T_W=1ns → 100ms
- edge= 300ps, fixed
- F_{REP}=max. 300MHz

ATTENUATOR: Suhner

- atten=10, 20 db
- impedance=50Ω
- B=4GHz

OSCILLOSCOPE: WavePro 7300/ LeCroy

- B=3GHz
- Sampling rate= max. 20GS/s

DUT

2 charge sens amps:

- CSPA – M. Ciobanu version
- FCSA – Al. Martemyanov version

2 broadband amps:

- DBA2 – P. Moritz
- BB4 – W. König

Measurements

About settings

TEST PULSE

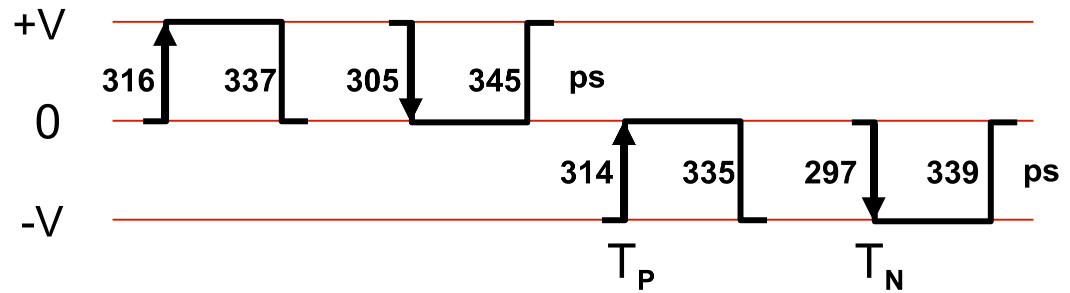
Selected

- T_P and T_N transitions
- minimum amplitude (500mV)

To have

- fastest transition
- best shape

Pulse generator can deliver:



ATTENUATOR

Selected

- minimum number of attenuators

Attenuator contribution to rise time (estimated)

No. of atten.	1	2	3	
B	4	2.8	2.3	**GHz**
T_R	88	124	152	**ps**
Influence on 300ps rise time	313	325	336	**ps**

Measurements

About settings

AMPLITUDE SCALE

- Rise time measurements →

2nd atten. effect (purple)

lower bandwidth effect (magenta)

Selected ≥10mV/div

U_{GEN}	500					mV
Atten.	0	10	20	10+20	10+20	db
U_{IN}	500	160	50	16	16	mV
T_N	297	301	299	305	338	ps
T_P	314	316	315	324	355	ps
Amplit. scale	100	50	10	10	5	mV/div

- Noise measurements →

lower bandwidth effect (magenta)

Selected ≥10mV/div, N_{pkpk}~ 1div

Noise	1.62	1.65	1.70	1.55	1.00	mV_{RMS}
Amplit. scale	50	20	10	5	2	mV/div

TIME SCALE

- Rise time measurements →

Selected 2ns/div (better estimated pulse amplitude)

T_R	305	304	304	ps
Time scale	0.5	1	2	ns/div

- Noise measurements

Selected 50ns/div

TRIGGER LEVEL

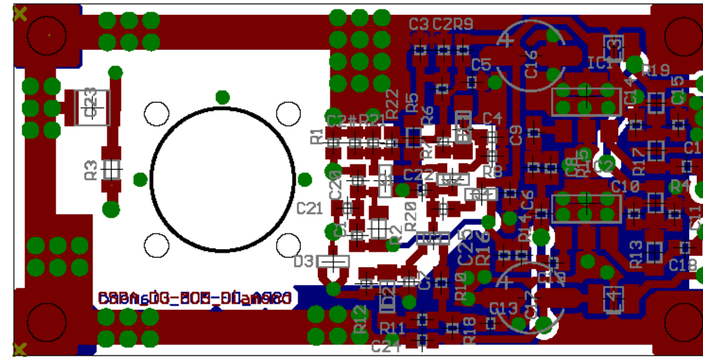
Selected 50% of pulse amplitude

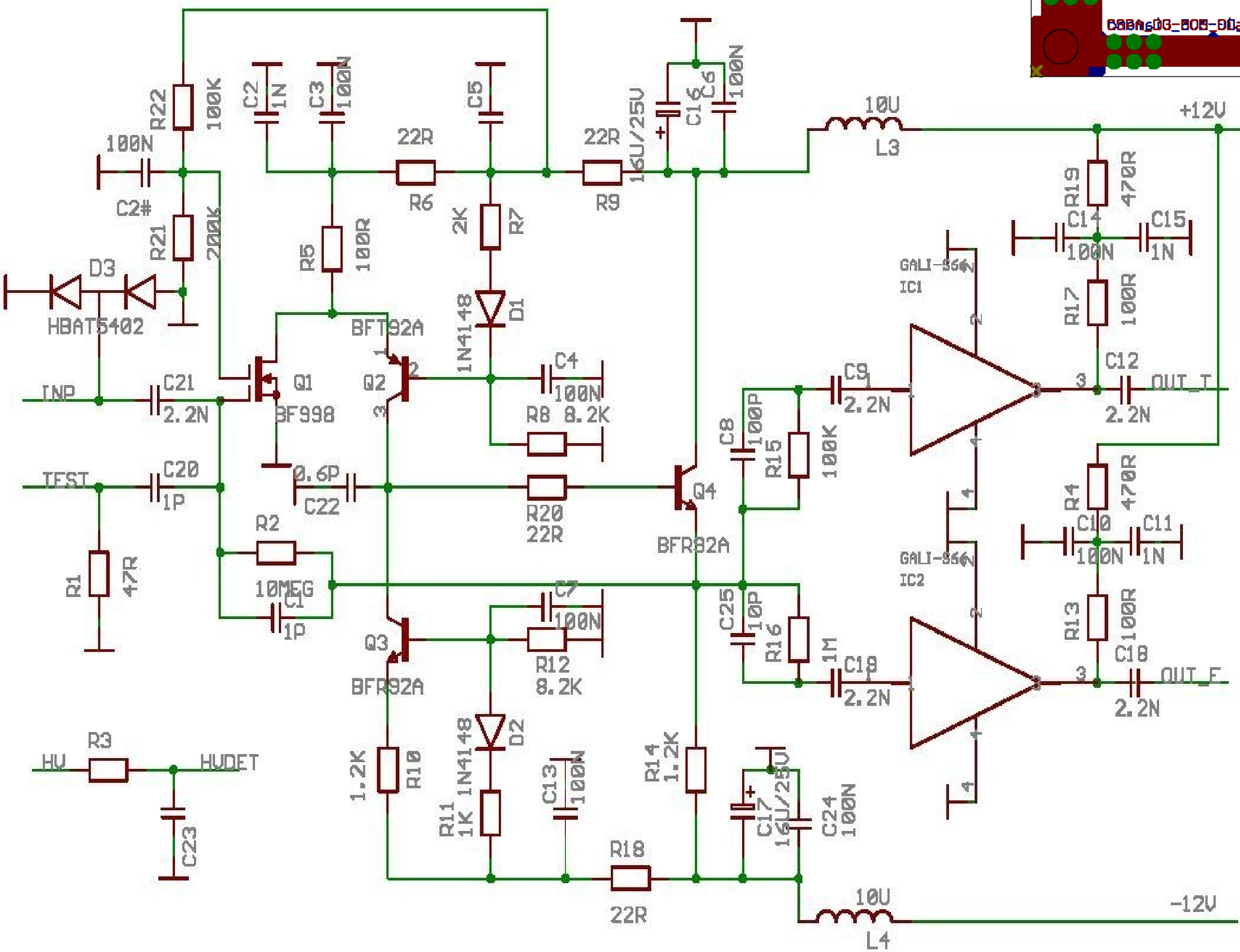
AVERAGE

Selected 1000 samples

Measurements

CSPA – circuit diagram





CS stage

- BF908, DG-MOS
- C_F=1pF (S=1mV/fC)
- τ_D=10μs

Diff+PZC

- τ_{diff}=5ns
- pasive

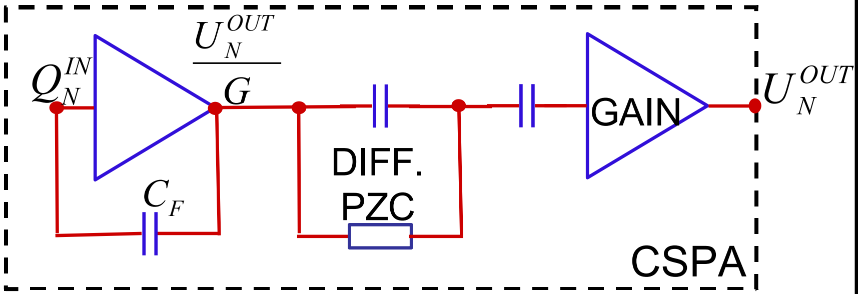
BB stage

- GALI 66, RF block
- Gain ≈10

Measurements

CSPA – Noise

► Output noise



Preamp	Output noise (U_N^{OUT})					Units
No. 1	860	994	970	946	928	μV_{RMS}
No. 2	875	979	994	970	947	μV_{RMS}
Amplit. scale	2	5	10	20	50	$\frac{mV}{div}$

20mV/div
50ns/div
20GS/s

Oscilloscope noise subtracted

► Input noise

$$Q_N^{IN}(e_{RMS}) = \frac{U_N^{OUT}(RMS)}{G} \cdot C_F \cdot \frac{1}{q_e}$$

where: $C_F = 1pF$

$G = 10$

$U_N^{OUT} \approx 1000\mu V_{RMS}$

$q_e = 1.6 \cdot 10^{-19} C$

$$\Rightarrow Q_N^{IN} = 625 e_{RMS}$$

(1fC=6250e)

► Comment: S/N ratio for MIPS in SC-DD

W_{DD}	100	200	300	400	500	μm
Q_{MIP}	3k6	7k2	11k8	14k4	18k	e
$\frac{Q_{MIP}}{Q_N}$	5.8	11.5	17.3	23.0	28.8	

Measurements

CSPA – Rise time

- Output signal level ≈60mV

10mV/div
1ns/div
20GS/s

Generator+osc. rise time subtracted

Preamp.	Input transition		Units
	neg.	pos.	
No. 1	753	719	ps
No. 2	666	619	ps

- Output signal level ≈200mV

50mV/div
1ns/div
20GS/s

Generator+osc. rise time subtracted

Preamp.	Input transition		Units
	neg.	pos.	
No. 1	775	670	ps
No. 2	688	570	ps

- Comment:

T_R≈700ps B≈500MHz

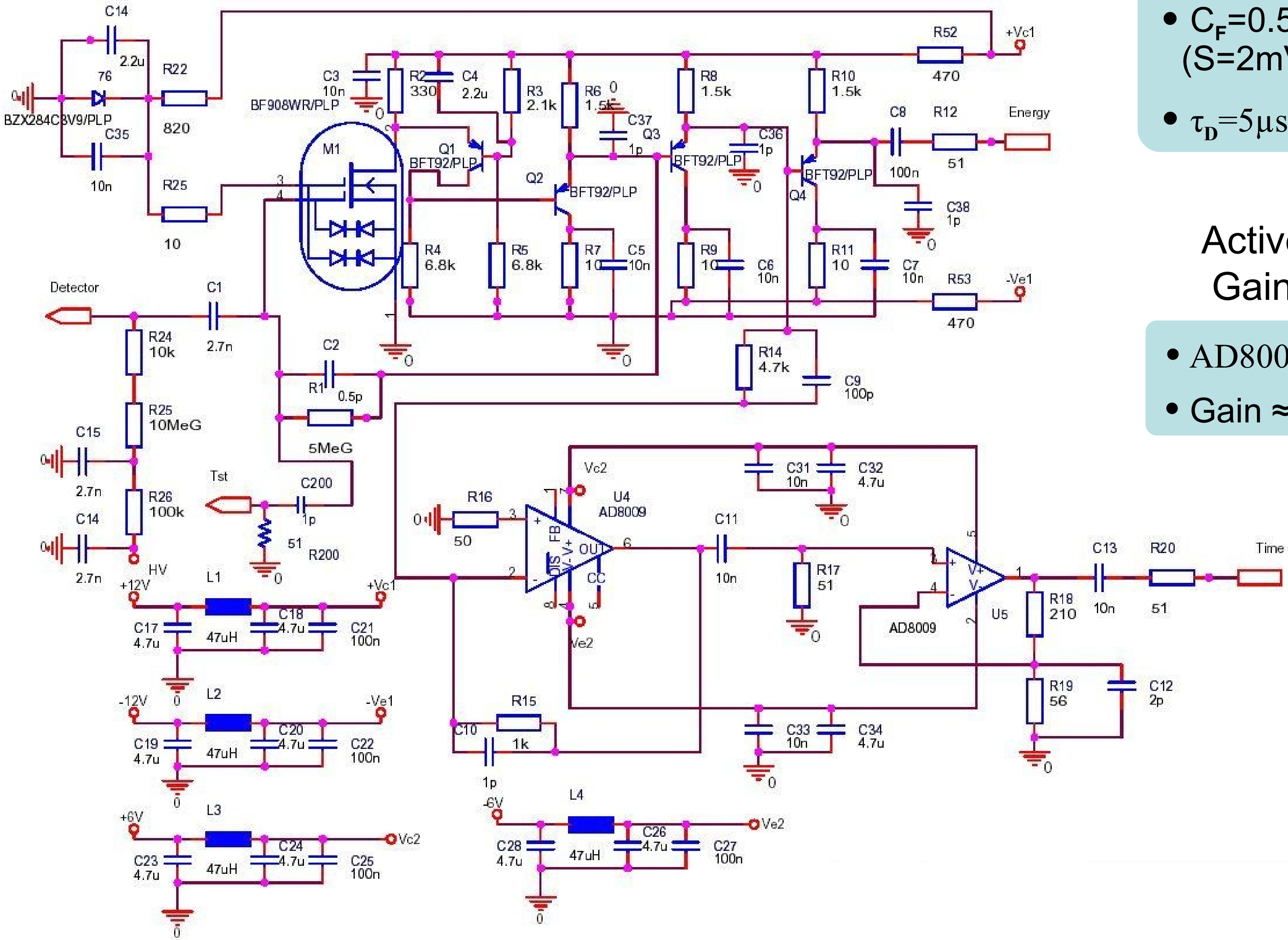
T_W≈1ns/100μm

(transit. time in SC-DD)

CSPA is fast enough to handle signals from SC-DD having W>100μm

Measurements

FCSA – circuit diagram



CS stage

- BF908, DG-MOS
- C_F=0.5pF (S=2mV/fC)
- τ_D=5μs

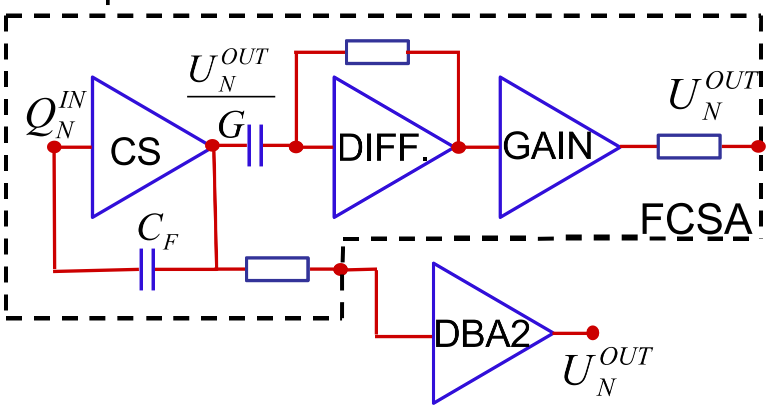
Active Diff.+ Gain stage

- AD8009, CF opamp
- Gain ≈80

Measurements

FCSA – Noise

► Output noise



Preamp	Output noise (U_N^{OUT})		Units
	CS+DBA2	CS+Diff.+GAIN	
No. 1	11.08	10.64	mV_{RMS}
No. 2	11.20	10.82	mV_{RMS}

20mV/div
50ns/div
20GS/s

Oscilloscope noise subtracted

► Input noise

$$Q_N^{IN}(e_{RMS}) = \frac{U_N^{OUT}(RMS)}{G} \cdot C_F \cdot \frac{1}{q_e}$$

where:

$C_F = 0.5\,pF$

$G = 70$ *for* DBA2

$G = 80$ *for* Diff.+GAIN

$U_N^{OUT} =$ *see table*

$q_e = 1.6 \cdot 10^{-19}\,C$

Preamp	Input noise (Q_N^{IN})		Units
	CS	CS+Diff.+GAIN	
No. 1	494	415	e_{RMS}
No. 2	500	423	e_{RMS}

Measurements

FCSA – Rise time

► Output signal level ≈120mV → T_R=2.25ns B=155MHz

at CS+Diff.+Gain output for both no.1 and no.2 preamps

20mV/div
2ns/div
20GS/s

Generator+osc. rise time subtracted

► Comment: time resolution (σ_T) comparison between CSPA and FCSA

$$\sigma_T = \frac{\sigma_N}{\left.\frac{\Delta V}{\Delta T}\right|_{Thr}} \approx \frac{\sigma_N}{\frac{U}{T_R}} = \frac{\sigma_N \cdot T_R}{U}$$

CSPA: $\sigma_N = 625\, e_{RMS}$

T_R=0.7ns B=500MHz

FCSA: $\sigma_N = 400\, e_{RMS}$

T_R=2.25ns B=155MHz

$$\frac{\sigma_T(CSPA)}{\sigma_T(FCSA)} = \frac{\sigma_N(CSPA)}{\sigma_N(FCSA)} \cdot \frac{T_R(CSPA)}{T_R(FCSA)}$$

for the same U

$$\frac{\sigma_T(CSPA)}{\sigma_T(FCSA)} \approx \frac{1}{2}$$

This result was <u>confirmed</u> by beam tests.

Measurements

DBA2 – Noise

Preamp	Input noise					Units
No. 77	13.9	21.0	24.1	23.2	22.7	μV_{RMS}
No. 16	13.9	20.7	23.7	22.8	22.3	μV_{RMS}
Amplit. scale	2	5	10	20	50	$\frac{mV}{div}$

50ns/div
20GS/s

Oscilloscope noise subtracted

BB4 – Noise

Channel	1	2	3	4	Units
Input noise	14.5	13.8	14.2	14.3	μV_{RMS}

50ns/div
20mV/div
20GS/s

Oscilloscope noise subtracted

DBA2 – Rise time

Preamp.	No. 77	No. 16	Units
T_R	160	135	ps
B	2.2	2.6	GHz
G	140	134	

500ps/div
50mV/div
20GS/s

Gen.+osc. rise time subtracted

BB4 – Rise time

Channel	1	2	3	4	Units
T_R	314	328	320	320	ps
B	≈ 1.1				GHz
G	201	204	211	204	

Output signal level ≈ 200mV

Counting rate effects

Baseline shift

- Campbell theorem (of mean square)

Randomly appearing pulses

Average rate *n*

Pulse shape *u(t)*

→

$$\overline{u^2} = n\int_{-\infty}^{+\infty} |u(t)|^2 \, dt$$

baseline shift

- Case of exponential shape

$$u(t) = A \cdot e^{-\frac{t}{\tau}}$$

→

$$\sqrt{\overline{u^2}} = 0.7 \cdot A\sqrt{n\tau}$$

- Examples

Charge sens. amps.

MIP particles
SC-DD, 350μ
CSA, C_F=1pF

↓

A= 2mV
τ =10μs
n = 10^9p/s

↓

shift = 140mV

Shaping amps.

G=200
τ =10ns

↓

A= 400mV
τ =10ns
n = 10^9p/s

↓

shift = 885mV

Counting rate effects

Amplitude distorsion

- Defining the problem

Randomly appearing pulses

Linear range U_L

Pulse shape $u(t) = A \cdot e^{-\frac{t}{\tau}}$

→ $n(1\%) = ?$ (counting rate corresponding to 1% distorted pulses in nonlinear region)

- Solution (derived from Campbell's theorem)

CSamp, AC coupled

$$n_{AC} = \frac{1}{3.12\tau}\left[\frac{U_L - A}{A}\right]^2$$

$$n_{AC} \approx \frac{1}{3.12\tau}\left[\frac{U_L}{A}\right]^2 \quad if \ \frac{U_L}{A} \geq 20$$

CSamp, DC coupled

$$n_{DC} \approx \frac{1}{\tau}\left[\frac{U_L}{A}\right]$$

$$if \ \frac{U_L}{A} \geq 20$$

Ratio

$$\frac{n_{AC}}{n_{DC}} = \frac{1}{3.12} \cdot \frac{U_L}{A}$$

- Examples

n_{AC}

U_{lin}/A \ τ	0.5	1	10 (μs)
20	$2.6 \cdot 10^8$	$1.3 \cdot 10^8$	$1.3 \cdot 10^7$
100	$6.4 \cdot 10^9$	$3.2 \cdot 10^9$	$3.2 \cdot 10^8$
1000	$6.4 \cdot 10^{11}$	$3.2 \cdot 10^{11}$	$3.2 \cdot 10^{10}$

n_{DC}

U_{lin}/A \ τ	0.5	1	10 (μs)
20	$4 \cdot 10^7$	$2 \cdot 10^7$	$2 \cdot 10^6$
100	$2 \cdot 10^8$	$1 \cdot 10^8$	$1 \cdot 10^7$
1000	$2 \cdot 10^9$	$1 \cdot 10^9$	$1 \cdot 10^8$

Ideas for future development

▶ The purpose: to improve time resolution $\sigma_T = \frac{\sigma_N}{slope}$

▶ Present status:

- BB amps are too noisy
- CS amps have too slow slope (imposed by transit time in SC-DD)

▶ Ideas for improvements:

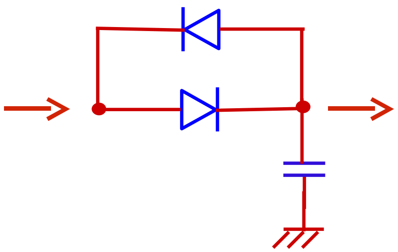
- Linear filter reduces the noise but in the same time worsens signals rise time (slope). Nonlinear filter which acts different on noise (low amplitude) and on signal (larger amplitude) may be a good idea.

- A thinner SC-DD has a shorter transit time and to compensate for smaller charge, it is possible to put in parallel a few thin cristals.

Ideas for future development

Nonlinear filter

❖ idea...



integrator

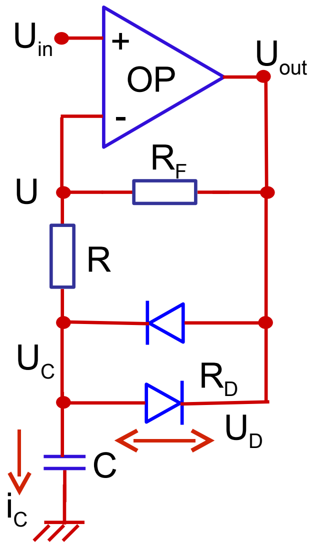
$T_{int} = C \cdot R_D(U_D)$

R_D = high (noise)

R_D = low (signal)

the simplest nonlinear integrator

❖ this really works...



...because we can controll diodes opening

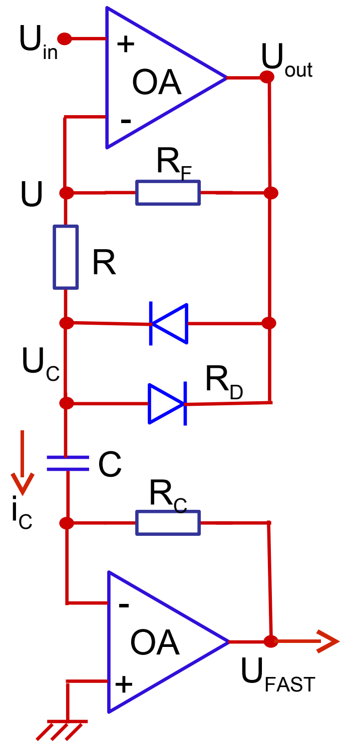
$$U_D = [U_{in} - U_C] \cdot \left[1 + \frac{R_F}{R}\right]$$

Attention!

$$i_C = C \cdot \frac{dU_C}{dt}$$

Faster signal than U_C !

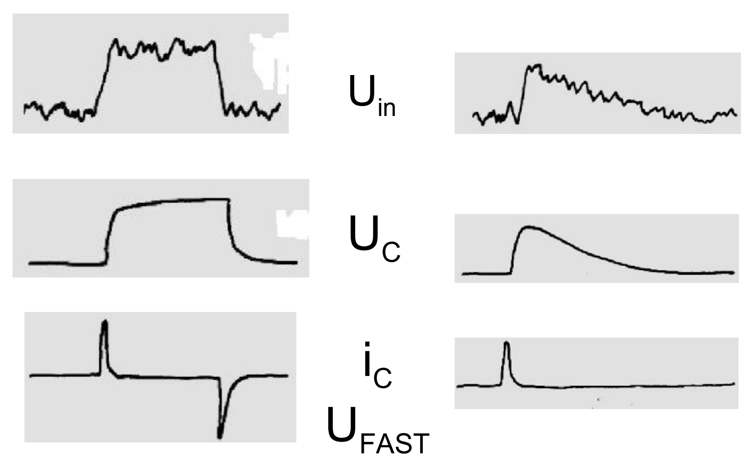
❖ this works better...



because it takes the advantage of using fast signal i_c converted in U_{FAST}

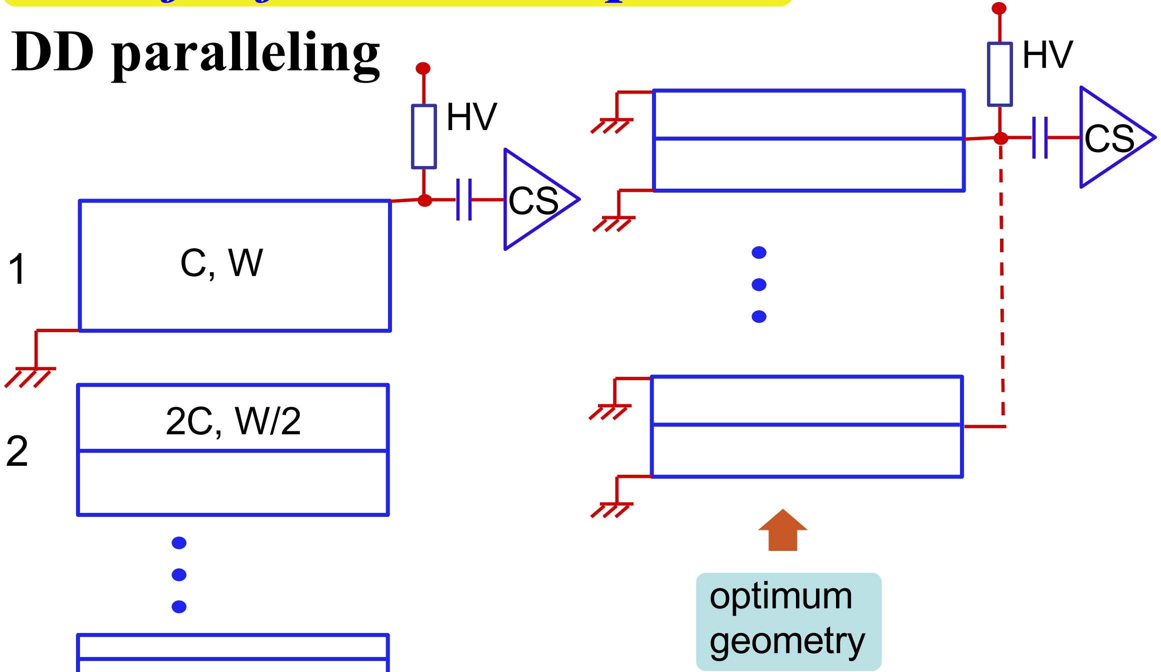
$$U_{FAST} = R_C \cdot i_C = R_C C \cdot \frac{dU_C}{dt}$$

❖ signal and noise handling...



Ideas for future development

DD paralleling



(no HV between adiacent detectors)

No. of DD	1	2	....	n
Width	W	$\frac{W}{2}$	....	$\frac{W}{n}$
Cap. (total)	C	4C	....	n^2C
Transit. time	T_w	$\frac{T_w}{2}$	....	$\frac{T_w}{n}$

► Example:

n	1	4
W	400μ	100μ
ϕ_{cont}	2mm	2mm
S_{cont}	3mm²	3mm²
C	0.37pF	6pF
T_w	4ns	1ns

* the same charge collected

List of participants

A. Caragheorgheopol [a]

A. Martemianov [b,c]

M. Ciobanu [b]

P. Moritz [b]

M. Pomorski [b]

M. Petris [a]

M. Petrovici [a]

E. Berdermann [b]

---

a – NIPNE – Bucharest, Romania

b – GSI – Darmstadt, Germany

c – IHEP – Moscow, Russia