which is the DC value at the output of the shaping amplifier...? aka the baseline? We dont necessary need to put it to ground. Maybe the dynamic range of the ADC is above zero (like from 1V to 6V).

The Baseline Holder

.doc]

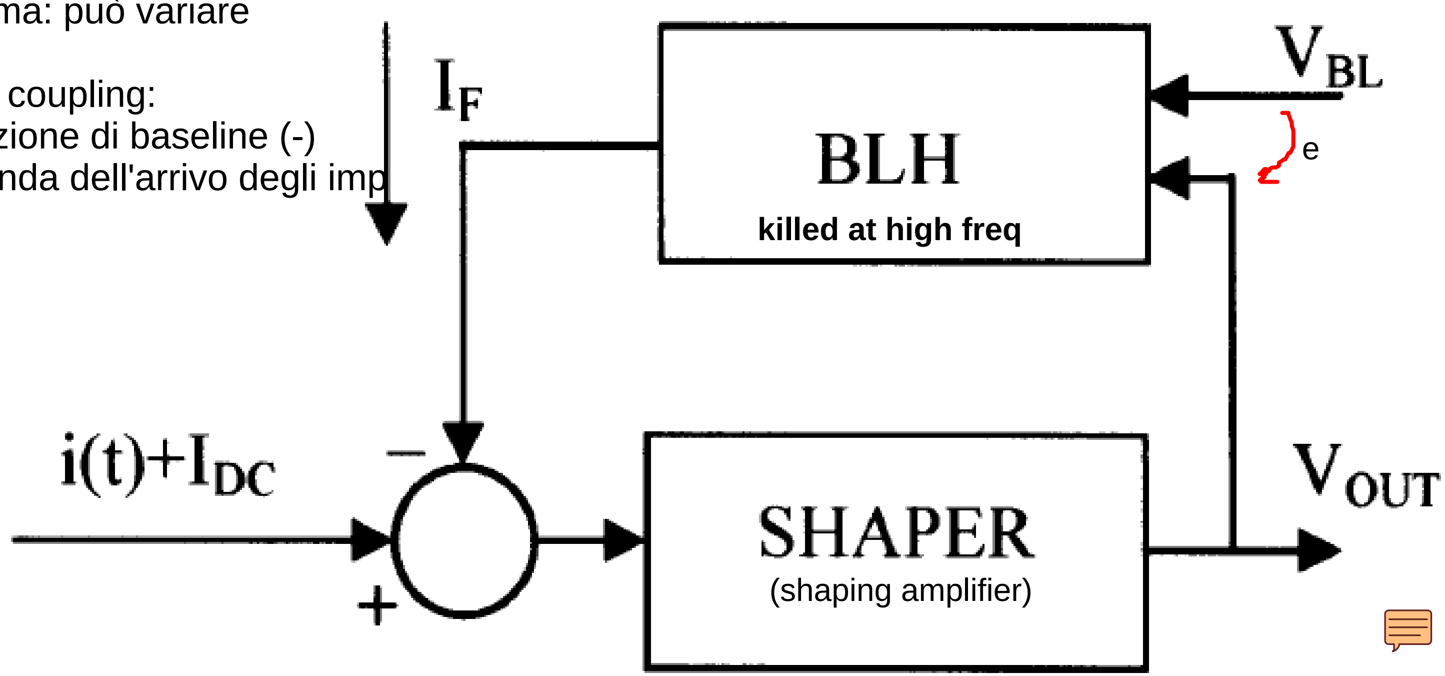
[quad.]

baseline due to:
- DC current from previous stages
- caratteristiche filtro

problema: può variare

con ac coupling:
- variazione di baseline (-)

a seconda dell'arrivo degli imp



It stabilizes the DC level of the baseline at the output of the shaper to V_{BL}

We'd like to set the baseline to a desirede level, may not be permitted by the internal stage of the amplifier. Also: we may have a DC current from the previous stages (and detector) and that may change during time => fluctuation of baseline in time, not nice b/c we dont know the stability of values we are converting. [disegno quad., corrente IdarkDC => VoutDC] quindi non sappiamo più come relazionarci coi valori letti. => QUICK AND DIRTY SOLUTION: AC COUPLING [DISEGNO QUAD.] Problema di questa soluzione: Viene imposto all'output a ZERO-AREA of the pulse: assuming squarewave at the input of the network, the output has again a square wave, but shifted vertically in maniera da avere area + = area - (*infatti val. medio deve essere 0). Quindi otteniamo una square wave dove l'area totale è zero. Ora l'amp. è posta sopra una baseline che è SOTTO zero. L'amp sopra zero è più piccola :(

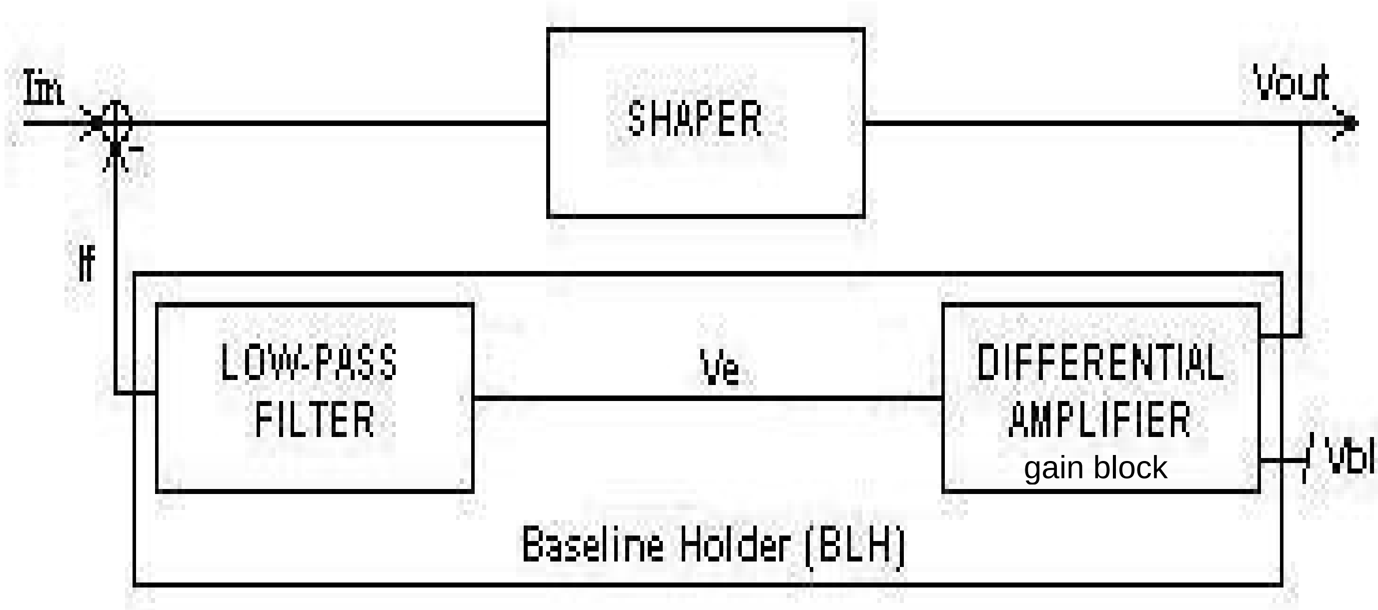
The Baseline Holder (BLH) -2

• goal: to guarantee a fixed value to the baseline at the output of the shaper (e.g. ground), also in case of arbitrary DC levels (and slowly variable) in the internal stages (problem in a system detector+preamplifier+filter fully DC coupled, e.g. with variable leakage current)

• basically, it realizes an AC coupling

• a non-linear version of the BLH reduces the well known effect of the shift of the baseline with the change of counting rate of the pulses in the classic AC coupling

The basic version



action:

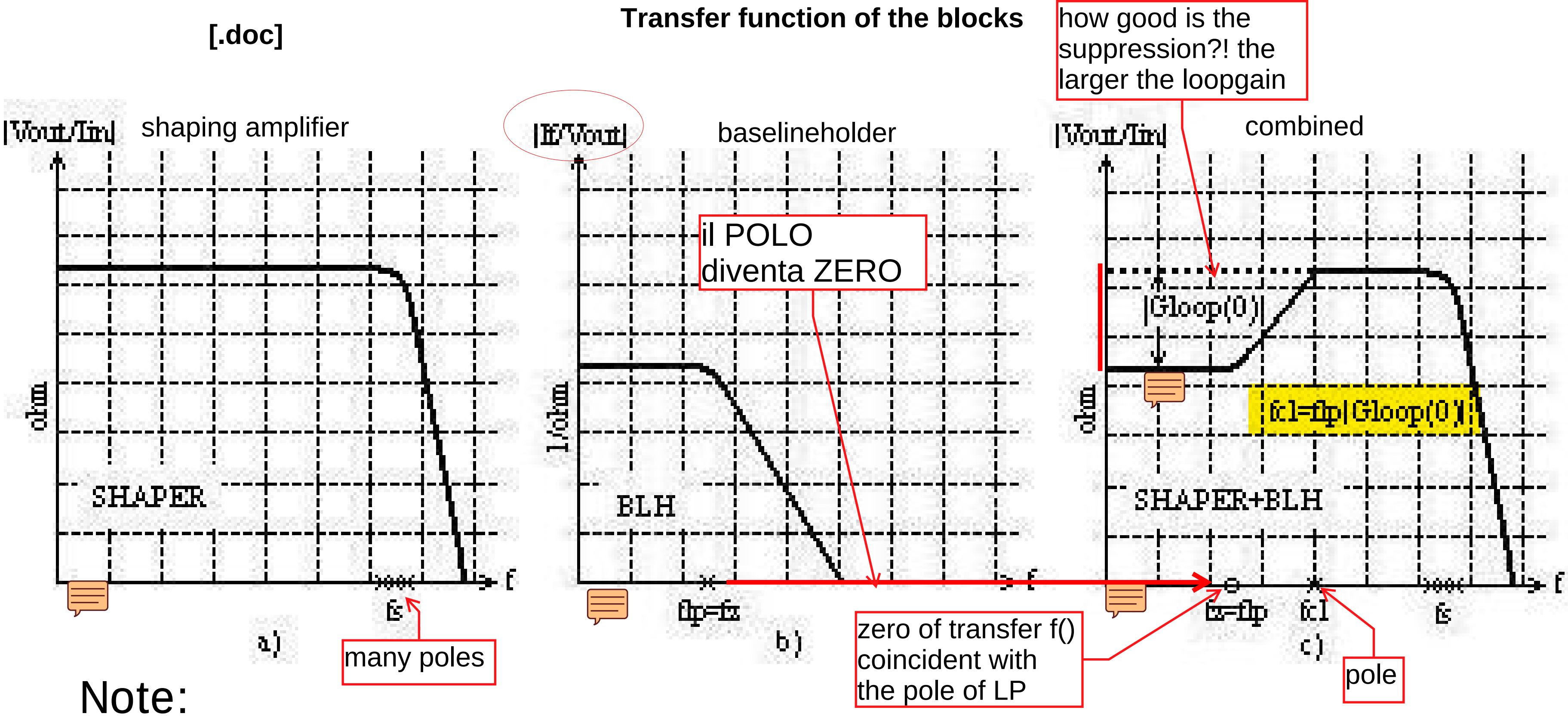
• at low frequency, the feedback absorbes Iin and the output voltage is determined by Vbl: Vout ≅ Vbl for any value of Iin

• at high frequency (in the signal bandwidth), the low-pass filter opens the loop and the output voltage is only determined by the signal Iin: $Vout = Iin(s) \cdot FDT(s)_{filter}$

⇒ the filter response with BLH can be approximated as an AC coupling

[.doc]

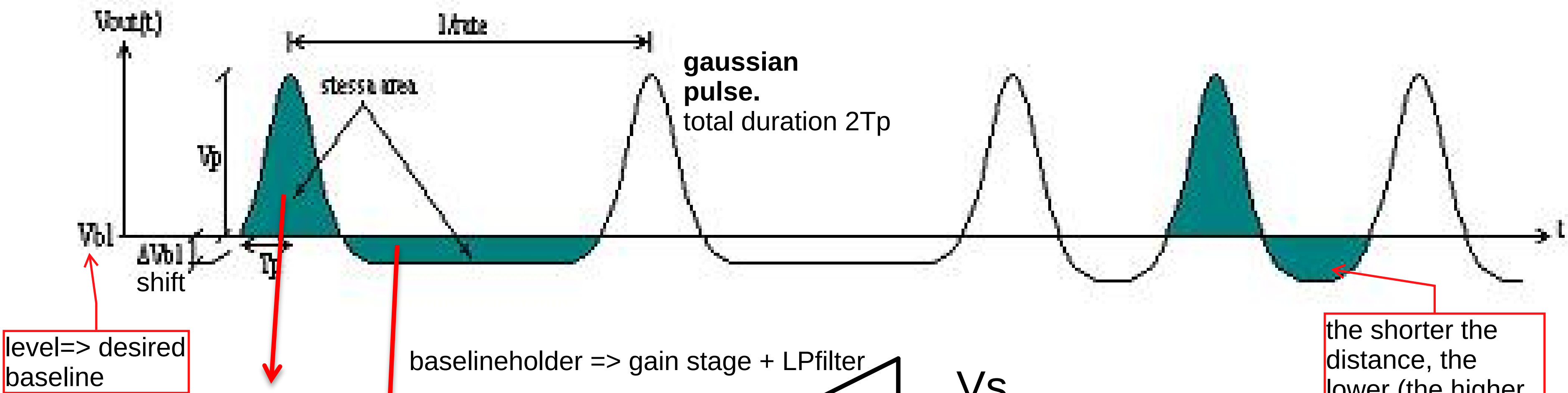
Transfer function of the blocks

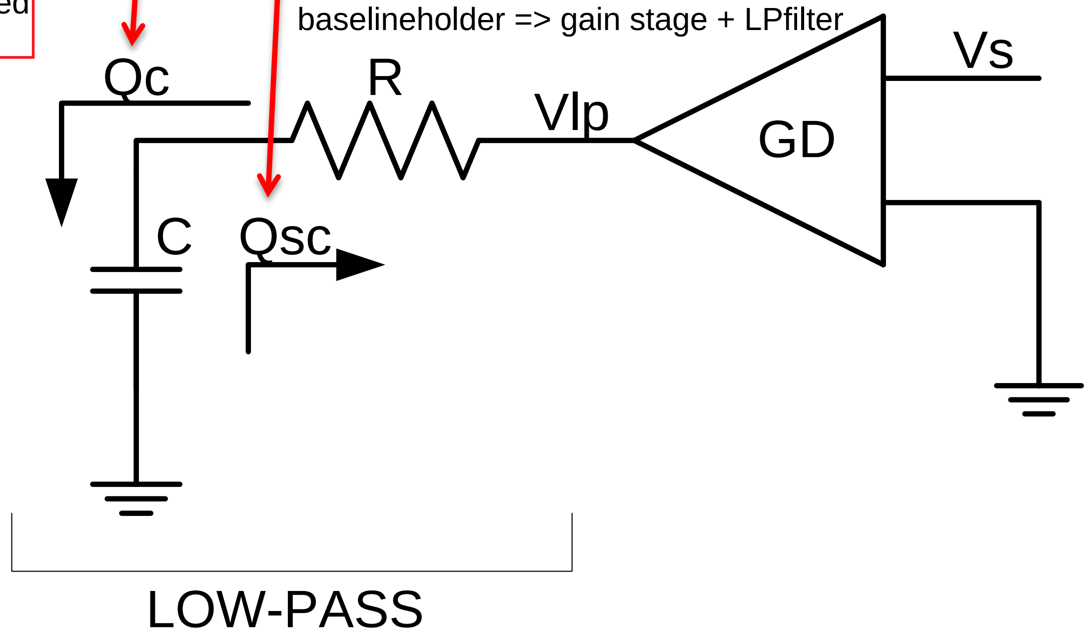


Note:

- the speed of the BLH to restore the baseline is related to f_{lp}
- f_{lp} difficult to place at very low frequency with an integrated circuit
- the precision of the baseline, for a given offset at the output of the shaper, is determined by Gloop(0)
- pole f_{c1} not to be placed at too high frequency to not interfere with the poles of the shaper and therefore to determine instability (against high Gloop(0))

Shift of the baseline (consequence of the AC coupling)

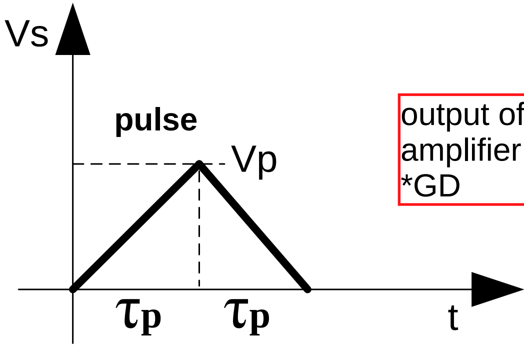




*"qual è l'unico modo per avere la scarica del condensatore? è se Vs fosse negativa. Hey, ma Vs è anche l'uscita finale! allora per forza di cose avrò una baseline, dato che quello caricato dovrà essere scaricato"

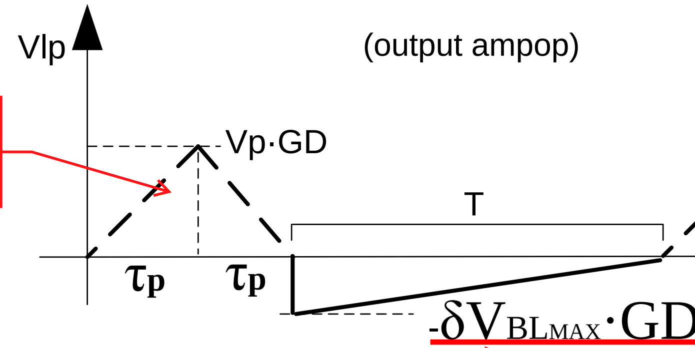
RC is where we have area cancellation. During pulse (positive pulse, positive area) the output of GD is positive, RC network charges capacitor (with Qc). We have the negative basline, because, if we have a negative basline the ouptut of GD is negative and we are taking back charges from capacitor. l'esistenza della negative basline è motivata dal fatt oche abbiamo bisogno di un negative voltage per fare il discharge del capacitor, e le due cariche devono essere le stesse. quindi proviamo a ridurre le cariche integrate.. la balance existe always!

quantization of baseline shift in standard AC coupling (standar baslineholder)



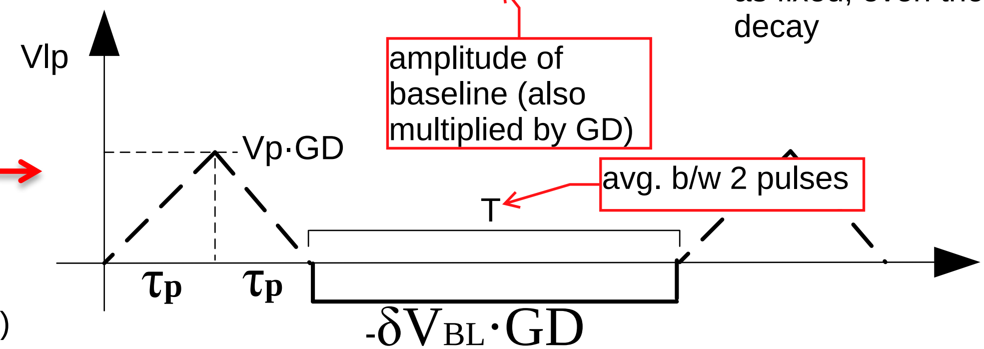
output of amplifier, pulse *GD

(output ampop)



I take the two and I integrate, the baseline is approximated as fixed, even tho' it should be decay

amplitude of baseline (also multiplied by GD)



Quindi, prendo queste tensioni, divido per R, ho una corrente e la integro sul cap (considerando Vc=0)

integrale area di un trianglo

$$Q_C = \int_0^{2\tau p} \frac{V_{LP}}{R} dt = \frac{1}{R} V_P G_D \tau_p$$

"close to the starting point, realistic b/c the duration of pulse tp is <<< time constant of lpfilter"

LP considered an ideal integrator

charge integrated by the baseline

$$Q_{SC} = \int_0^{T} \frac{|V_{LP}|}{R} dt = \frac{1}{R} \delta V_{BL} G_D T$$

shift of the baseline increases with the rate of occurence of the pulses

physical understading (charge int. by cap = charge abs by bhl):

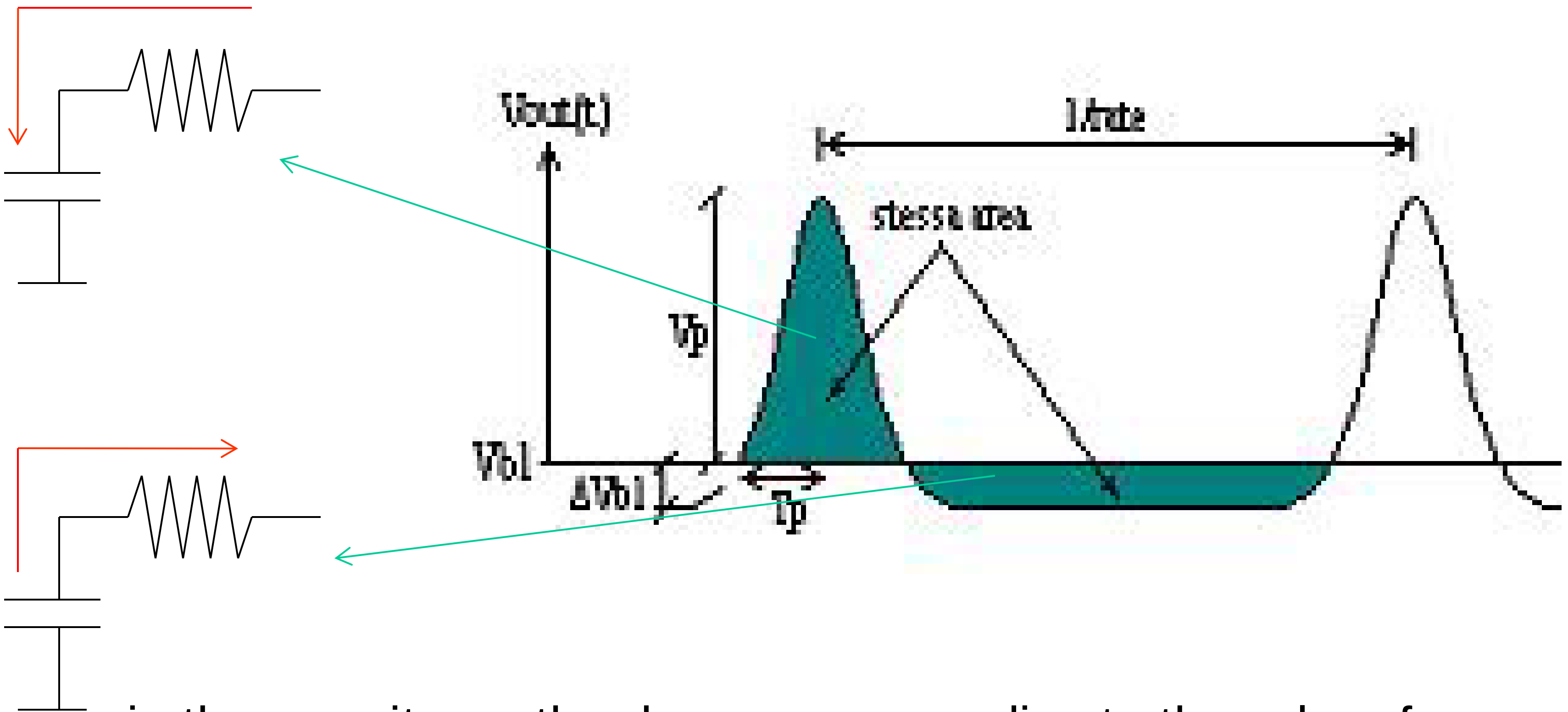
$$Q_C = Q_{SC} \qquad \Rightarrow \qquad \delta V_{BL} = \frac{V_P \tau_p}{T} = V_P \tau_p rate$$

(avg. rate)

baslineshift: proportional to amplitude of pulse, to duration of pulse, and is divided by average distance. The baseline shifts more, shorter is the distance of pulses! the result is the same that apply to the ACcoupling!

key issue: integration of the signal area in the low-pass stage

charge integrated => area of gaussian pulse

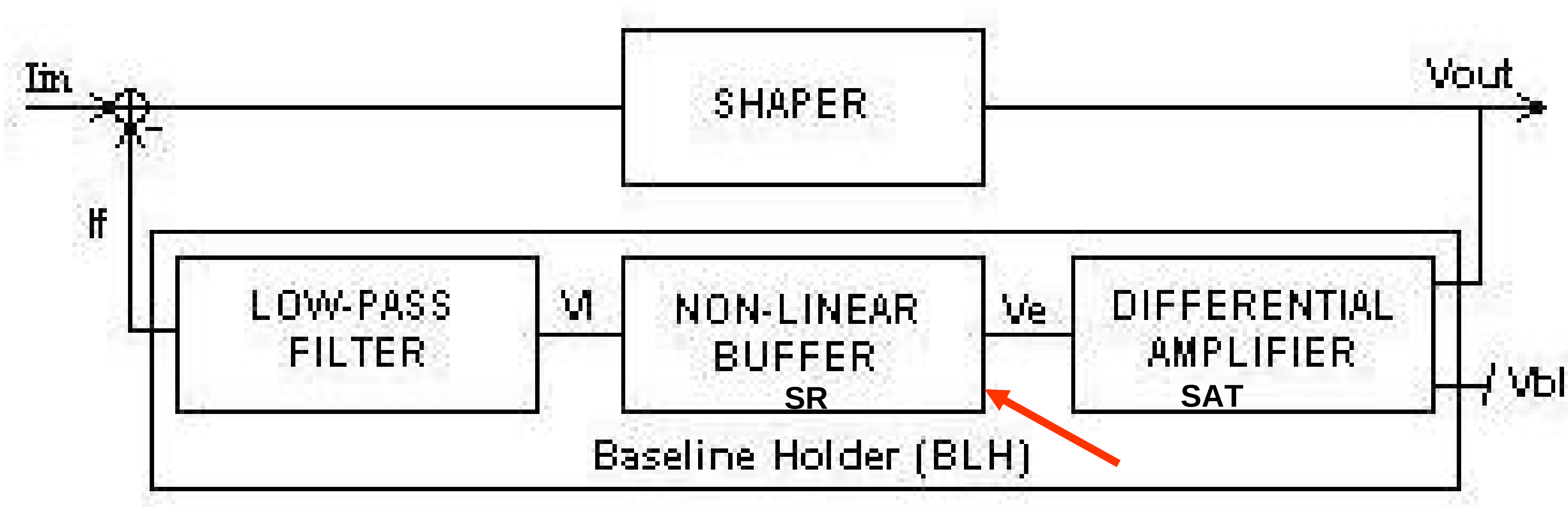


in the capacitance the charge corresponding to the pulse of amplitude Vp is integrated during the interval 2Tp and this charge is given back during the interval 1/rate

idea: try to reduce the charge integrated (referred to Vout) in order to reduce also the charge given back (which creates the shift)

If we integrate less charge from the cap. we have less charge to take back from the baseline.

Modify the BLH to reduce the shift at high counting rates



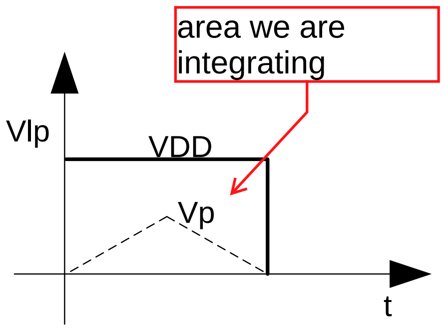
• increase the gain of the differential amplifier in order to push it to saturate its output voltage (attention to not increase too much the Gloop)

• insert a non-linear buffer to introduce a slew-rate after the response (saturated) of the differential amplifier

⇒ the effective area of the pulse "integrated" is lower than before, consequently the baseline shift is smaller

we act on the baselineholder block, introducing 2 tricks: 1) let amplifier saturating, **clamping the max. amount of charges that can be integrated** into the cap (sat. only during pulse) 2)introduce a SLEW RATE STAGE to limit amount of charges integrated into the cap (SR only during pulse)

1^{st} action: push the differential stage into saturation



$$Q_C = \int_0^{2\tau p} \frac{V_{DD}}{R} dt = \frac{1}{R} V_{DD} 2\tau_p$$

$$Q_C = Q_{SC}$$

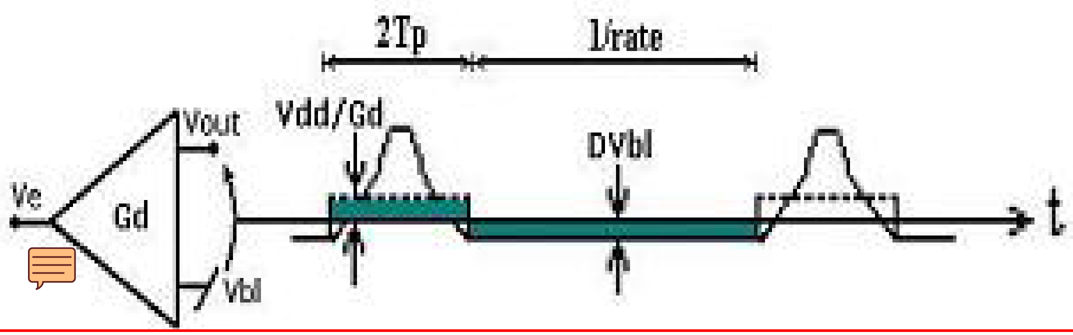
$$\frac{1}{R} V_{DD} 2\tau_p = \frac{1}{R} \delta V_{BL} G_D T$$

is always the Q_{SC} as before which is discharged in a linear way also now

$$\Rightarrow \quad \delta V_{BL} = \frac{V_{DD} 2\tau_p}{G_D} rate = V_P \tau_p rate \boxed{\frac{2V_{DD}}{V_P G_D}}$$

standard ac coupling term

<1 for large Gd

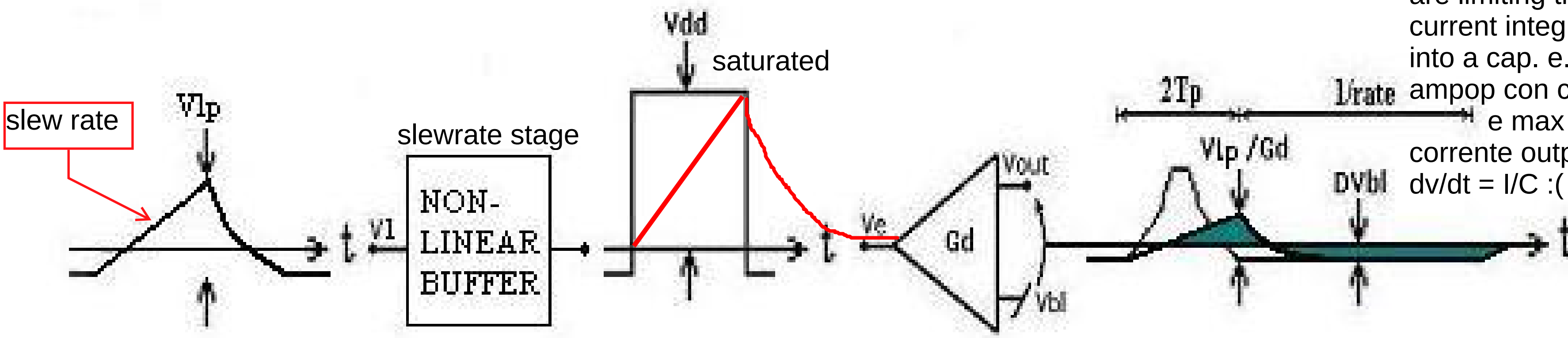


note: the behavior of the circuit can be represented as an equivalent linear system where at the input of the differential there are rectangles of amplitude V_{DD}/G_D instead of Gaussians

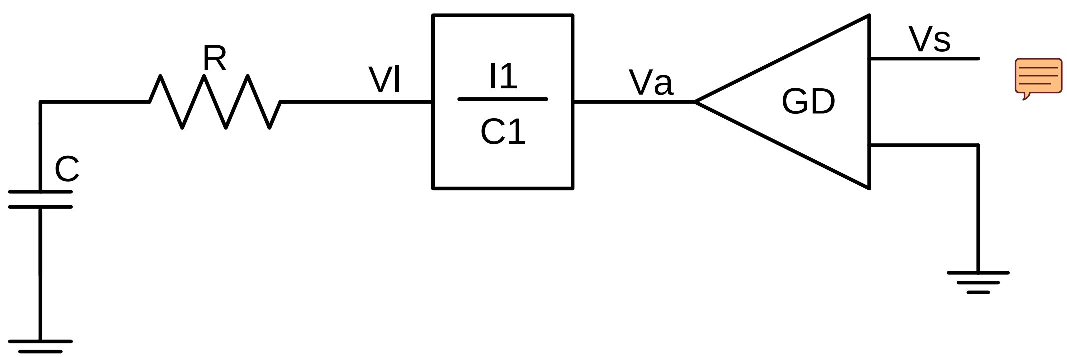
It means: I increase A LOT gain Gd of diff. stage. so that whatever pulse I have, the output of the stage is not vpeak*gd, but Vdd (Saturated output). So we calculate again the charge integrated (vdd, sat. voltage, integrated for 2taupeak).the area is bigger.. but the trick is in the discharging! I assume that the amp is saturating for the pulse, but not the basline. so **baseline is still amplified by Gd**! wihtout saturation! THE SIGNAL SATURATES THE AMP. TO VDD! the baseline is not saturating, so we have the same formula! in the equality of charges, in the charging Gd disappears, for the negative is still there.. putting equality I get a baselineshift smaller!

2^{nd} action: introduction of the non-linear buffer

slewrate: whatever effects that limit the rise time of a voltage, because we are limiting the current integrating into a cap. e.g. ampop con carico C e max corrente output I, dv/dt = I/C :(



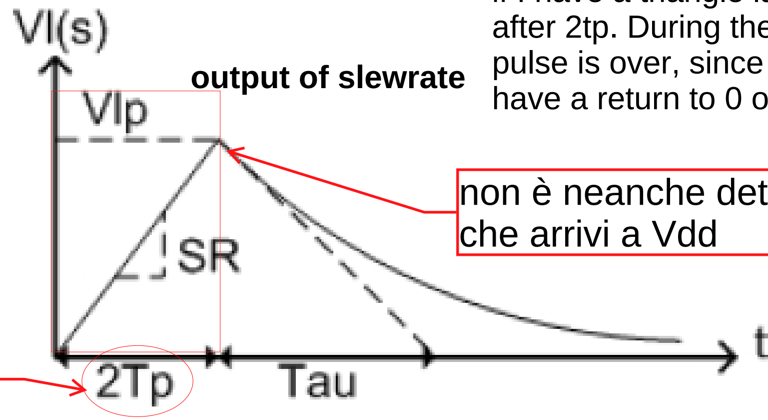
• the low-pass filter is not directly connected to the output of the differential stage but a non-linear buffer is inserted among them in order to introduce a slew-rate which, therefore, further reduces the fraction of the area of the output pulse which is integrated



We create on purpose a ramp limitation. So with the slew rate, the area integrated will be smaller! It's not even a rectangle, is a kind of ramp, followed by an exponential. thus, the negative area will be even smaller.

*questo triangolo non centra nulla con quello dei pulse, è il rettangolo VDDsat. rallentato per lo SR

if I have a triangle lasting 2*Tp., the output will get the peak after 2tp. During the duration of the pulse I rise up. When the pulse is over, since the slewrate is associated with a cap, I'll have a return to 0 of the cap with an exp. decay.



non è neanche detto che arrivi a Vdd

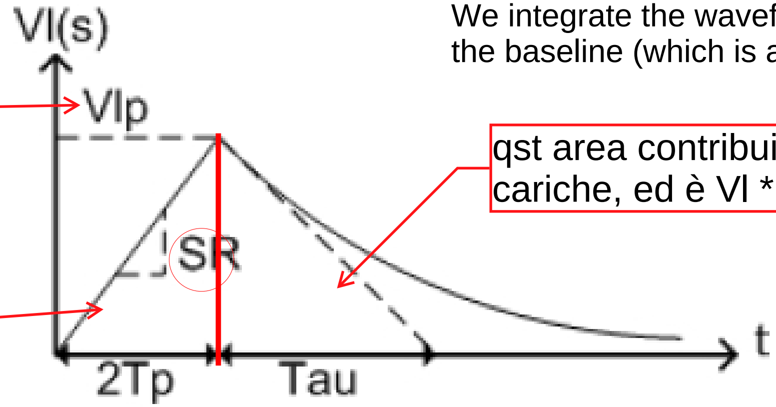
durata del rettangolo, coincidente con durata del pulse

Figura 5.5: Risposta del buffer non lineare

We can observe on Vl(t) that the non-linear buffer produces a ramp as long as the output of the amplifier is saturated; then, once reached the peak value Vlp, Vl(t) returns to the starting value with an exponential decay having time constant Tau (the first phase corresponds to the charge integrated in a capacitance in a slew-rate regime while the second phase regards the RC discharge of such capacitance).
As seen before, such non-linear circuit can be represented to an equivalent linear circuit in which each event produces at the input of the differential amplifier the response of fig. 5.5 scaled by a factor 1/Gd.

*quanto carico avendo una sat. Vlp in ingresso dipenderà dallo slew rate! Se è ultra basso allora sarà ultra basso

Vlp * 2Tp /2



we can repeat (not repeated in the detail) the area calculation. We integrate the waveform, and we put it equal to the area of the baseline (which is always the same).

qst area contribuisce alle cariche, ed è Vl * tau

Figura 5.5: Risposta del buffer non lineare

area exp: peak*timeconstant

senza SR carico 2*Tp*Vdd

area NL

...we obtain this formula

$$\Delta(Vbl) \cong \frac{Vlp}{Gd}(Tp+\tau)\cdot rate \cong \frac{(2Vdd)(Tp)(rate)}{Gd}\cdot\frac{(Vlp)(Tp+\tau)}{(2Vdd)(Tp)}$$

final formula

THIS IS IDENTICAL (slide 9)

new term

some manipulations..

$$\Delta(Vbl) \cong \frac{\boxed{(2Vdd)(Tp)}(rate)}{Gd}\cdot\boxed{K}$$

saturation

non-linearity

$$K = \frac{(Vlp)(Tp+\tau)}{(2Vdd)(Tp)}$$

good candidate to be < 1 :). On the den. I have Vdd, numerator Vlp, which depends on the slew rate.. but Vlp can be as small as we like

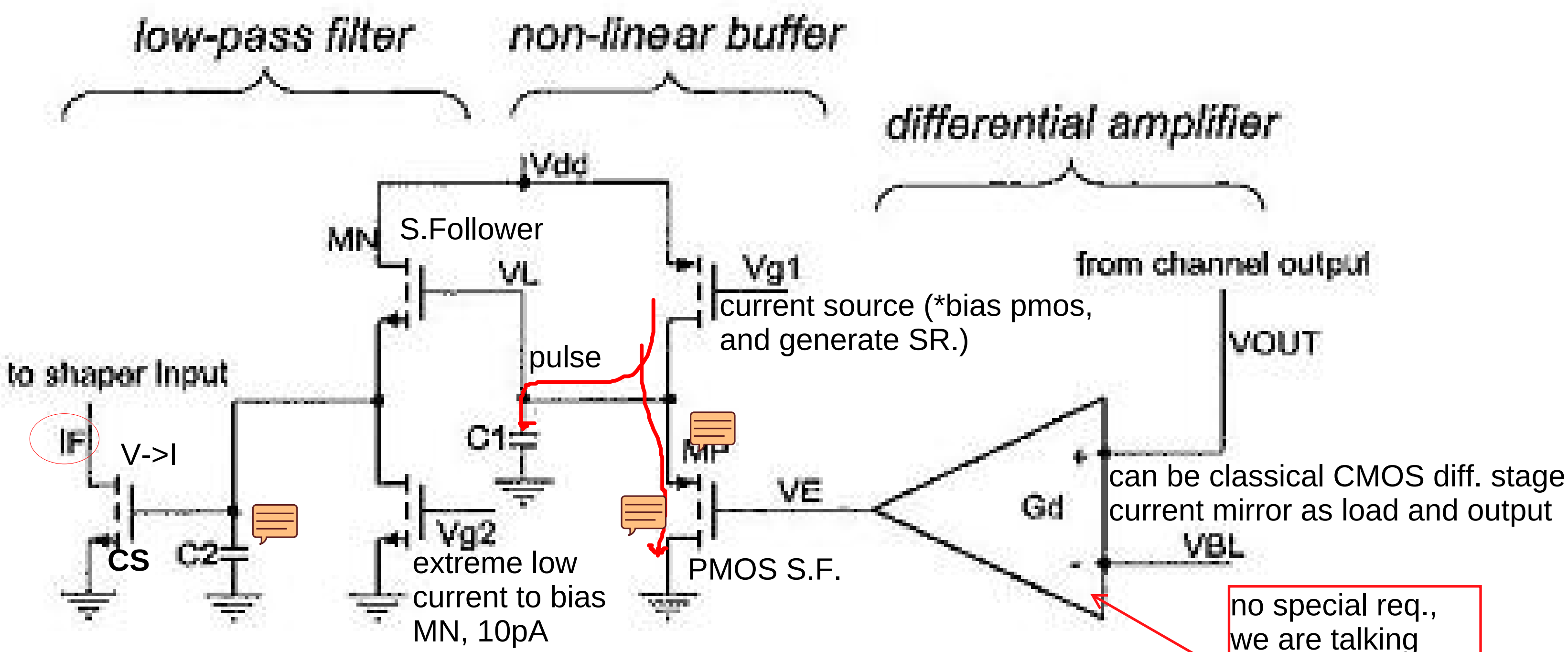
K express the ratio between the area at the output of the non-linear buffer and the area of the rectangle at the output of the differential stage and such ratio has to be minimized (to make the SR to provide an additional advantage after the saturation)

More aggressive the SL, the smaller is Vlp.

Circuital implementation

(De Geronimo, et.al, IEEE-TNS, 2000)

this is in parallel to the filter



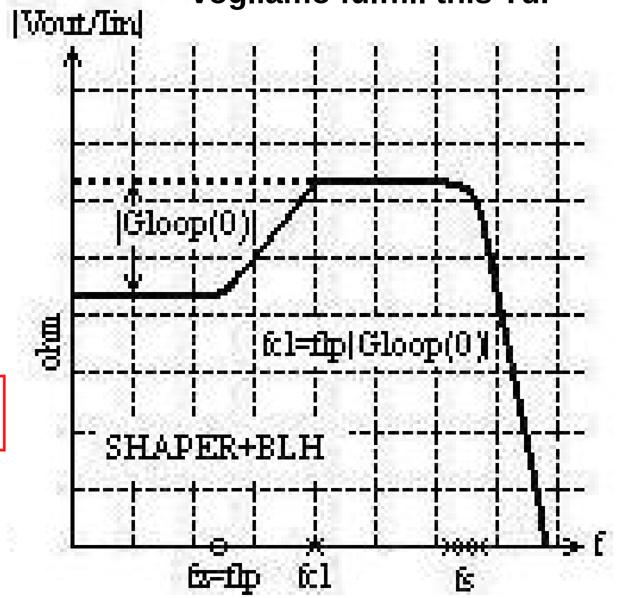
$\tau = 1/gm_{MN} \cdot C2$ $\quad$ $SR = I_{buffer}/C1$

Buffer => introduce a slewrate, but the slewrate has to be active only for the positive pulse! has to limit only the triangle. For the negative baseline, all the assumption are that nothing changes. For the negative baseline Gd HAS NOT to saturate, and slewrate should be simply gain 1. Indeed we see a **PMOS source follower**, with current source Vg1. This is also at the same time a slewrate stage [quad.]. We get slewrate = I/C, thus we can decrease I or increase C.If baseline is negative, hte gate of pmos gets negative, the transistor is in normal operation, SO IM NO MORE IN SLEW RATE , I have a traditional source follower, which simply amplify by 1. Ok we have C1 which just make a time constant. **Lowpass filter**: **nmos source follower** loaded with large C2. [metodo mos bias really low => really high 1/Gm, unreliable]. Non facciamo bias con voltage, p' è impossibile controllare ocn la tensione he abbia **10pA**! Però possiamo usare demultiplier mirror per ottenere quella corrente come bias. Ed in fine solo **CommonSource,** infatti dobbiamo fare feed di corrente.

"linear regime, laplace"

Design example

*..."gli altri sono follower"



only of the baselineholder block!

gain differenziale

gm of output common source (V->I)

$$\frac{If(s)}{Vout(s)} = \frac{Gdgm_0}{(1+\frac{sC_1n_pVth}{Id_p})(1+\frac{sC_2n_nVth}{Id_n})}$$

due to the preseence of C1 which makes the SR. We can neglect it, **much faster**

10pA, we can set it low :)

2 Source followers, 2 time constant.
1 is on purpose (c2) and one si not (c1)

TAU = 1/gm * C2 gm=I/(nVth)

$$|Gloop(0)| > 100 \qquad fcl < \frac{fs}{100} \qquad fcl = flp\,|Gloop(0)|$$

ref. value of 100kHz: shaping time in the order of uS. realistic

condition of freq. baselineholder

$$flp < \frac{fs}{(100\,|Gloop(0)|)} \qquad 100Khz$$

Estrando dalla formula della TdF.. ottengo:

$$\frac{C_2n_nVth}{Id_n} > \frac{1}{2\pi 10Hz}$$

viene fuori 10Hz dalla formula prima

best we can have :(

$$C_2 = 10pF,$$

$$Id_n < 2\pi \cdot 10Hz \cdot 10pF \cdot 25mV \cong 10pA$$

WE HAVE THIS CURRENT TO BIAS!

Measurements on a baselineholder.

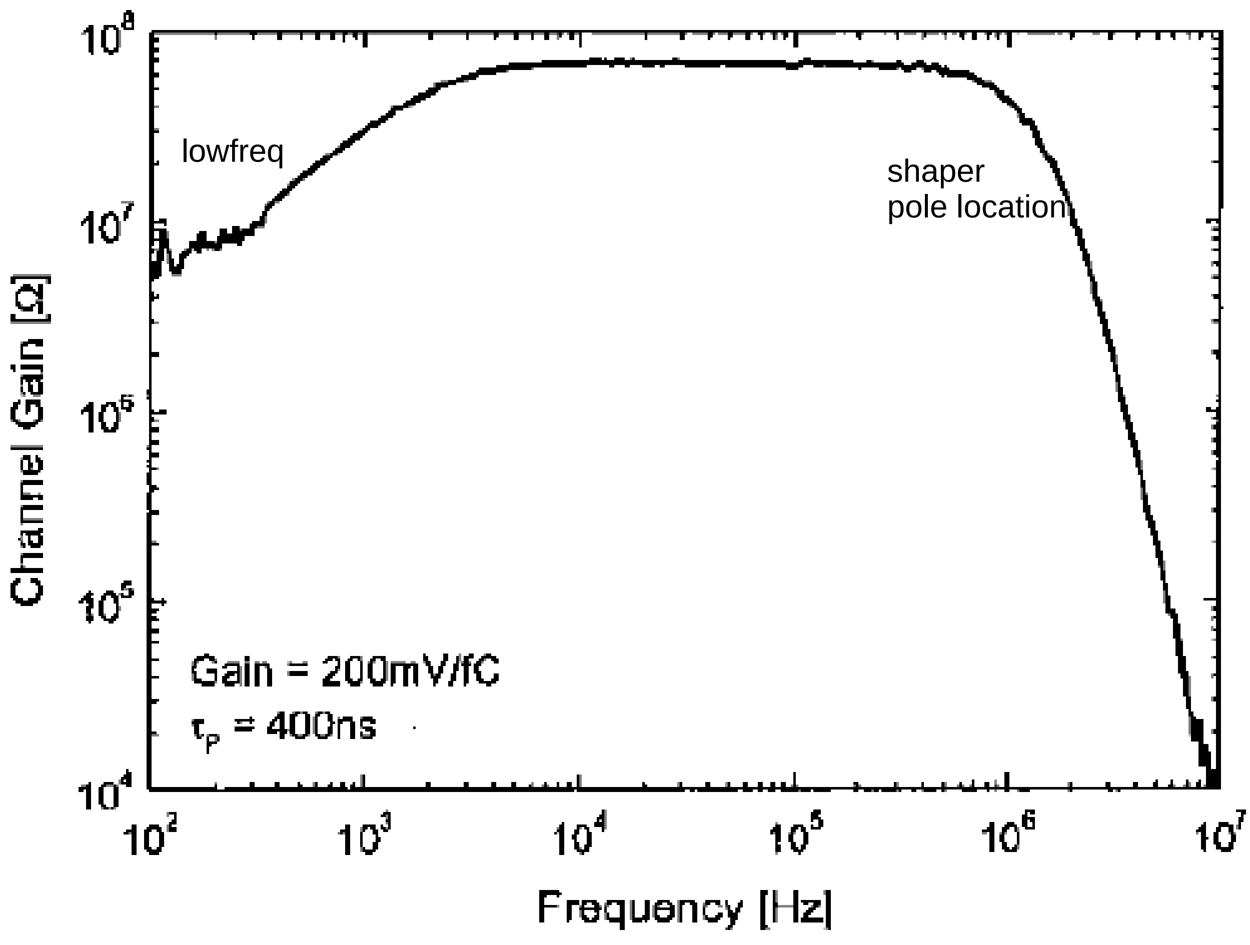


Figure 3: Measured channel small signal transfer function.

insensitivity of a complete (det->amp>filter) to change of detector dark current. claim inizio: dc b/w detector current and output of shaper. questo fa vedere che senza il circuito, cambiando il detector current, c'è uno shift significativo, con anche sat. a vdd. Invece con la baseline holder lo shift è praticamente negligible.

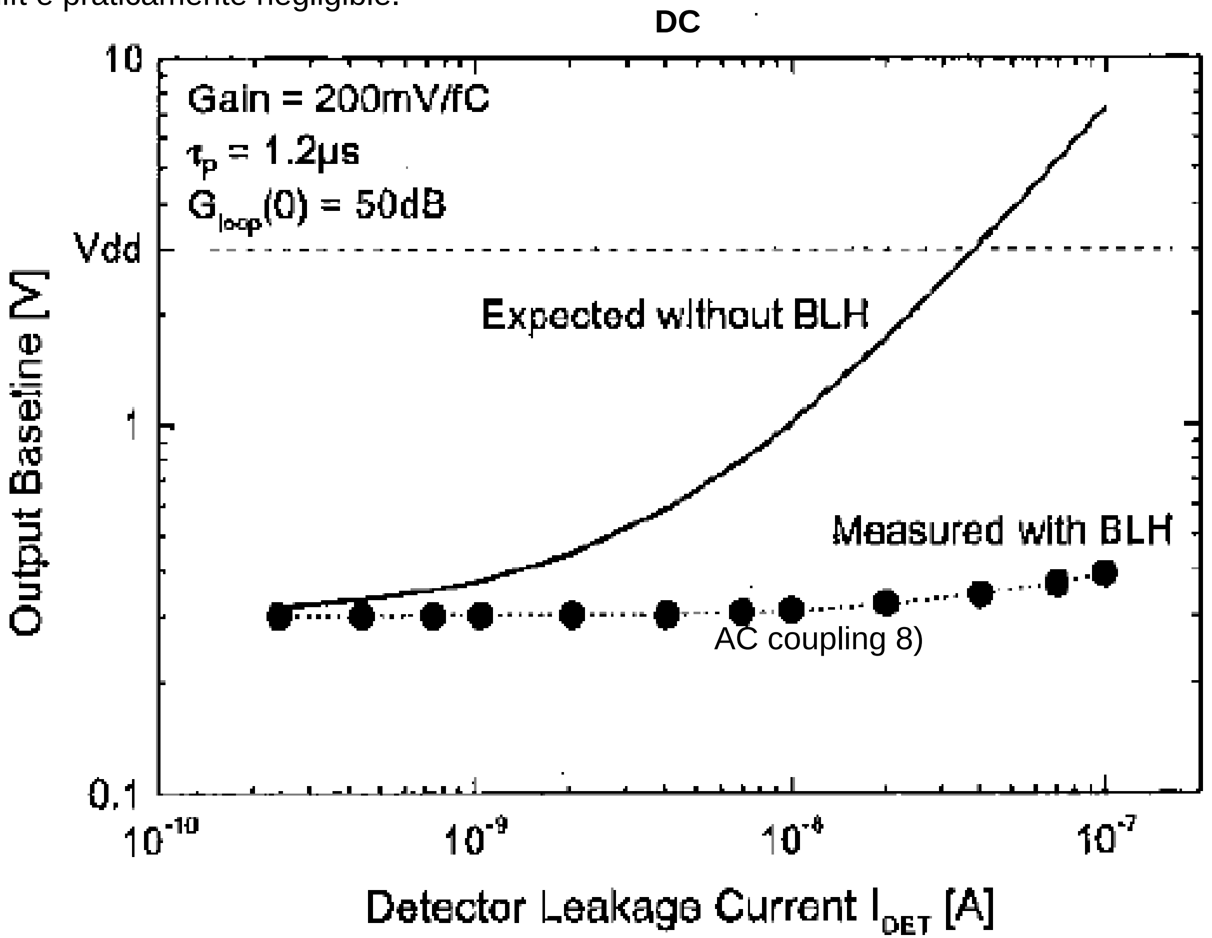


Figure 4: Output baseline dependence on detector leakage current I_{DET}.

In addition to simply AC coupling, effect of the NL tricks etc.

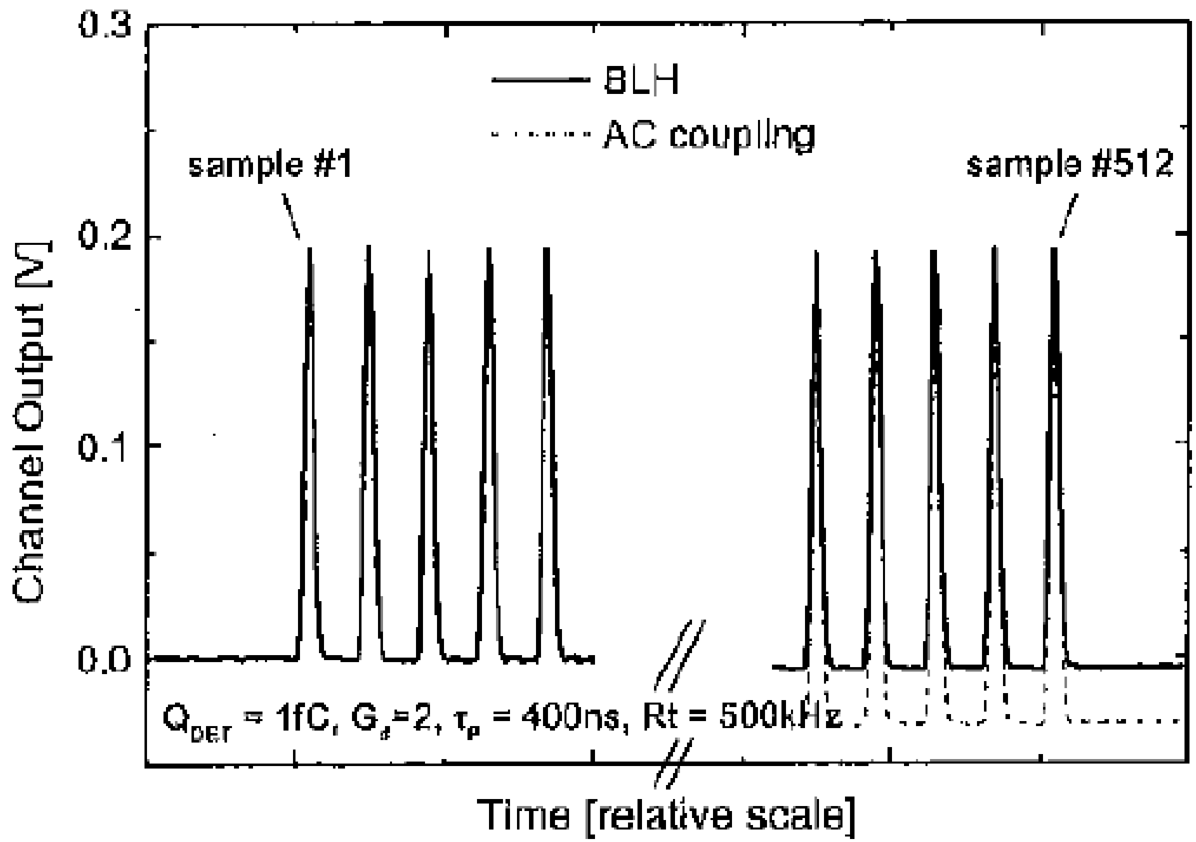
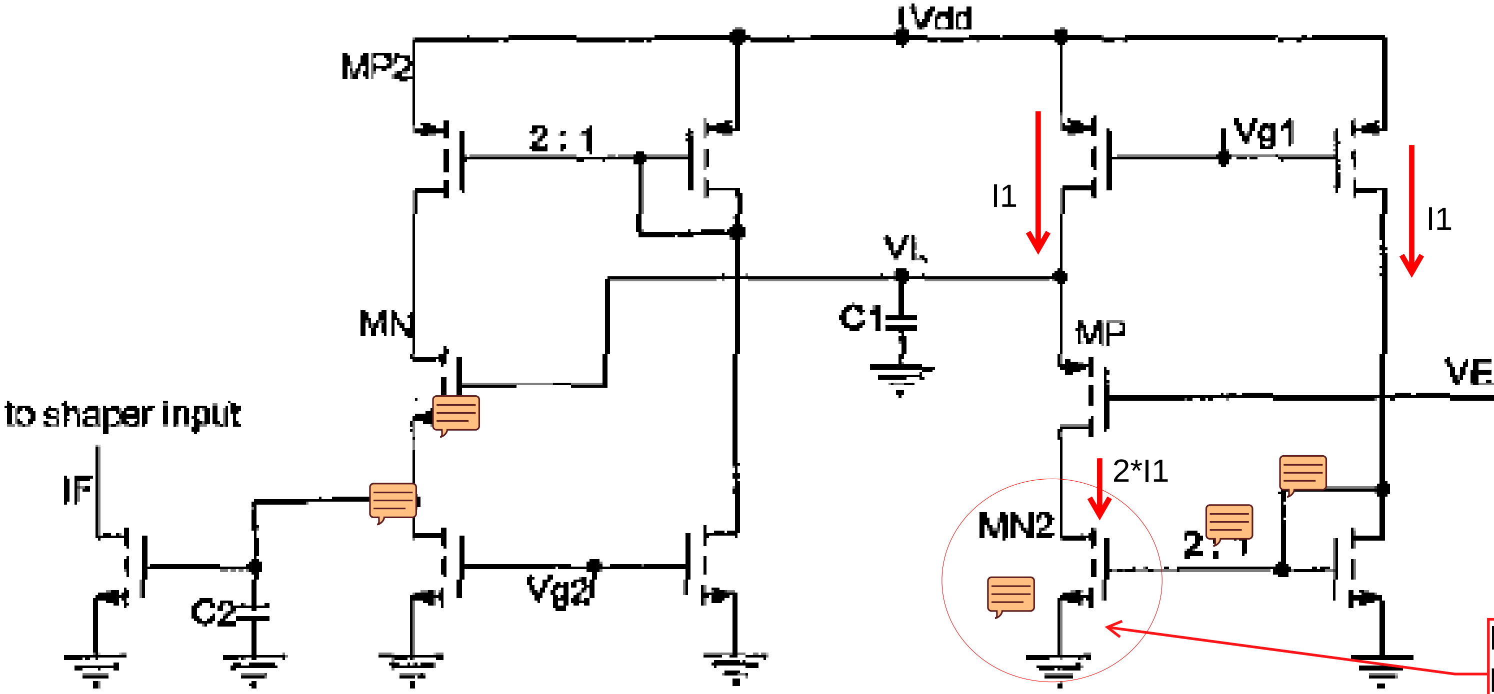


Figure 7: Experimental comparison for $Q_{DET} = 1fC$ and $Rt = 500kHz$ between ASIC channel output and case with BLH disabled and ac-coupling with same time constant of the approximated high-pass filter.

Suddently we apply a train of 500 pulses. Con solo AC coupling iniziamo con una baseline ketp to 0, dopo 5 pulses non vediamo shift in baseline, perché l'integrale è ancora in nostro favore. Alla fine invece, dopo 500 pulses, vediamo che c'è stato un negative shift del baseline! Usando invece il NL baselineholder, dopo 500 pulses c'è un microshift del baseline, ma è molto piccolo! tl;dr effetto delle NL aggiunte.

Limitation of the current available in the follower in case of large negative swings (e.g. because of negative tail of the Gaussian signal)

[quad]

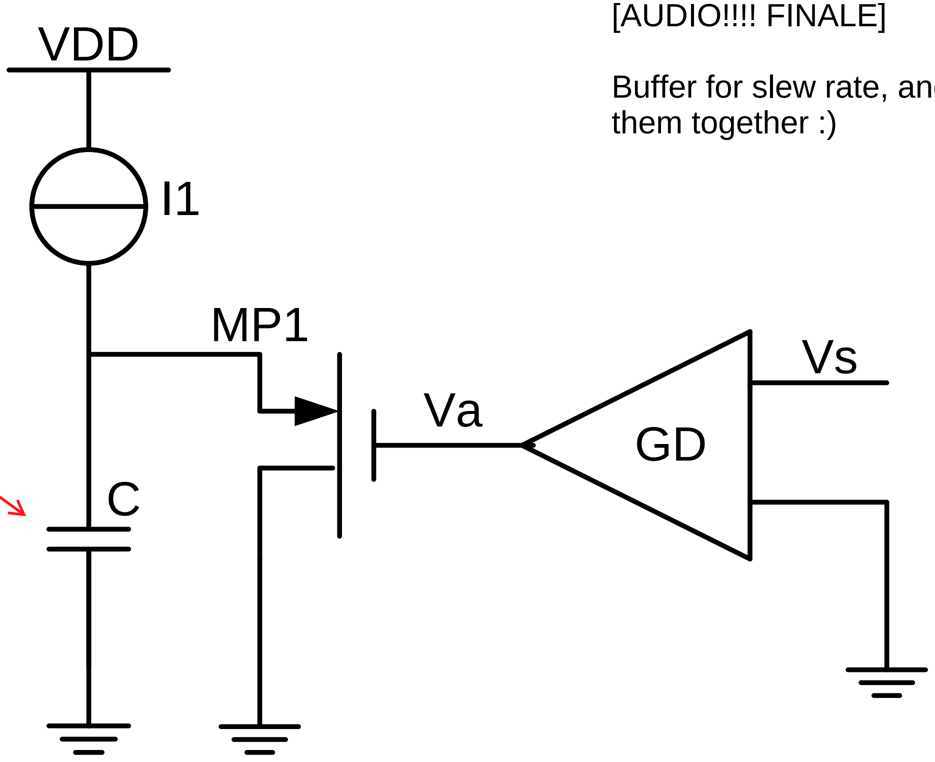


la corrente è presa da un current mirror

Considering the slewrate stage with PMOS and diff amplifier, when we design a shaping amplifier, and we have a complex costellation of poles, we cant garantee a nice and perfect position of poles.We cant really fix poles in perfect position. Due to a nonperfect poles position, in the response of the semigaussian shaper, we may have a little **negative undershoot**. Piccolo. No effetto sul rumore. This may have DRAMATIC effect of the stage of baseholder! abbiamo un boost Gd enorme! che però doveva saturare la parte positiva lol! Con un negative undesired part of the pulse.. il gain è ancora alto. ed abbiamo una saturazione anche negativa!! Con la sat negativa, il sourcefollower switches on A LOT!!! (infatti |Vgs| increases a lot!!) Il transistor increases the current, which is not taken by the Igen which is limited, and thus taken from the cap c1!!! this cretes an enormous -Dq sul cap, which later, has to be slowly restored by the Igen (VG1) This produces some distortions in the output. Solution: we limit current of the follower, with an additional current generator on the drain.This way, when the negative step happens.. Quindi avremo l'enormous current ma limitato da I2 e quindi limitato.

Possible idea: BLH with saturation of Gd, SR and LP in a single stage

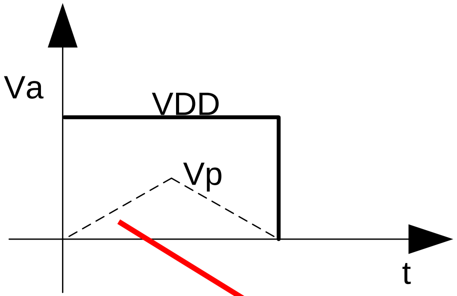
*prima avevo una cap per SR ed una CAP per POLO, ora sono la stessa.. servirebbe cmq CS dopo.



[AUDIO!!!! FINALE]

Buffer for slew rate, and buffer for POLE, why don't I join them together :)

*questioni di farlo.. timing del circuito? dato da 1/gmMP1, oppure da I1? non dovrebbe mantenere il polo? va via?



$$Q_C = 2I_1\tau_p$$

$$2I_1\tau_p = \frac{1}{R}\delta V_{BL} G_D T \Rightarrow \delta V_{BL} = \frac{I_1 2\tau_p R}{G_D} rate$$

possiamo calcolare il vantaggio

$$\delta V_{BL} = \frac{I_1 2\tau_p}{G_D}\frac{V_{th}}{I_1} rate = 2\tau_p \frac{V_{th}}{G_D} rate \frac{V_P}{V_P}$$

$$\delta V_{BL} = V_P \tau_p rate \frac{2V_{th}}{V_P G_D} = V_P \tau_p rate \cdot K$$

$$K = \frac{2V_{th}}{V_P G_D}$$

indipendent from I_1 e C

Critical issues:

- pole of LP dependent from the transistor state
- pulse to VDD directly on Va injects charge directly on C by means of Cgs of the transistor (it happens also in the other configurations but with less critical effects)

A comparison between various configurations

Vp=1V

τ_p=4us

rate = 100k counts/s

Gd=10

I1=10nA

C1=200fF

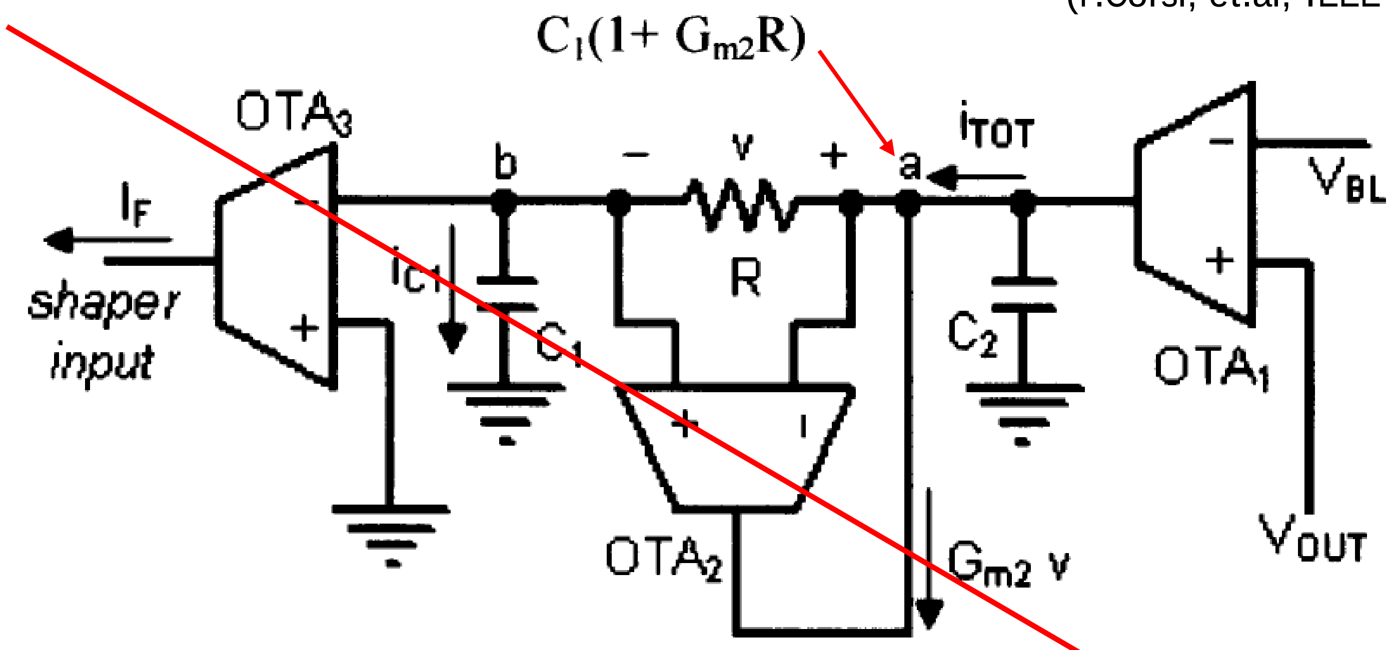
Vdd=1.7V

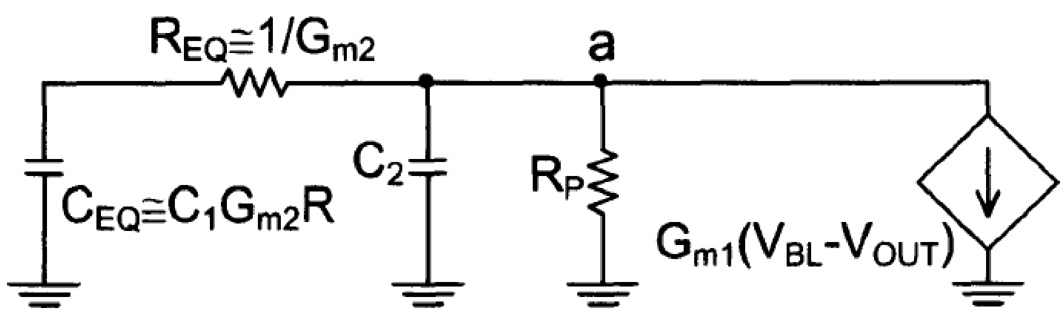
$$\boxed{\delta V_{BL} = V_P \tau_p rate \cdot K}$$

	K	$\boldsymbol{\delta V_{BL}}$
just ac coupling **Basic**	1	400mV
saturation of Gd	$\frac{2V_{DD}}{V_P G_D}$ = 0.34	136mV
satur.+SR	$\frac{I_1}{C_1}\frac{2\tau_s}{V_P G_D}$ = 0.04	16mV
single stage: sat.+SR+LP	$\frac{2V_{th}}{V_P G_D}$ = 0.005	2mV

Another example of implementation of the low-frequency pole

(F.Corsi, et.al, IEEE-NSS, 2008)





$$\omega_0 \cong \frac{1}{R_P C_1 G_{m2} R}$$