Wideband pulse amplifiers for the NECTAr chip

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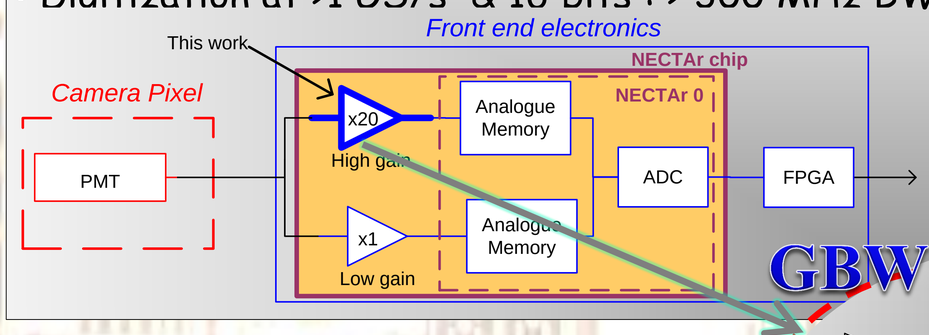
Abstract NECTAr collaboration FE option for the camera of the CTA is a 16 bits and 1-3 GS/s sampling chip based on analogue memories including most of the readout functions. Here we describe the input amplifiers of the NECTAr ASIC. A fully differential wideband amplifier, with voltage gain up to 20 V/V and a BW of 400 MHz. Being impossible to design a fully differential OpAmp with an 8 GHz GBW product in a 0.35 CMOS technology, an alternative implementation based on HF linearised transconductors is explored. The output buffer is a class AB miller operational amplifier, with special non-linear current boost.

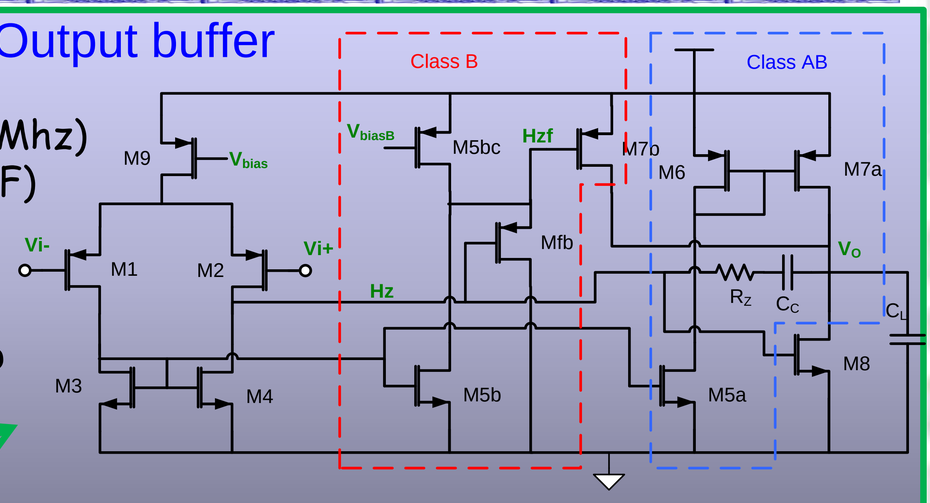
NECTAr :New Electronics for the Cherenkov Telescope Array (CTA)

- Front end electronics of the camera of CTA
- Single GHz sampling chip : analogue memories
- Digitization at >1 GS/s & 16 bits : > 300 MHz BW

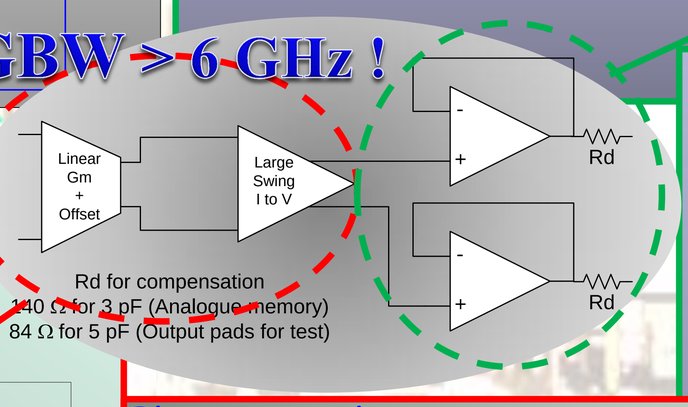


Output buffer

- Unity gain wideband follower (500 Mhz)
  - Large capacitive loads (up to 5 pF)
  - Slew rate of about 1 V/ns
- Power consumption of 1 to 3 mW
- Applications
  - Output stage of the gain 20 amp
  - Input buffer of NECTAr0 SCA

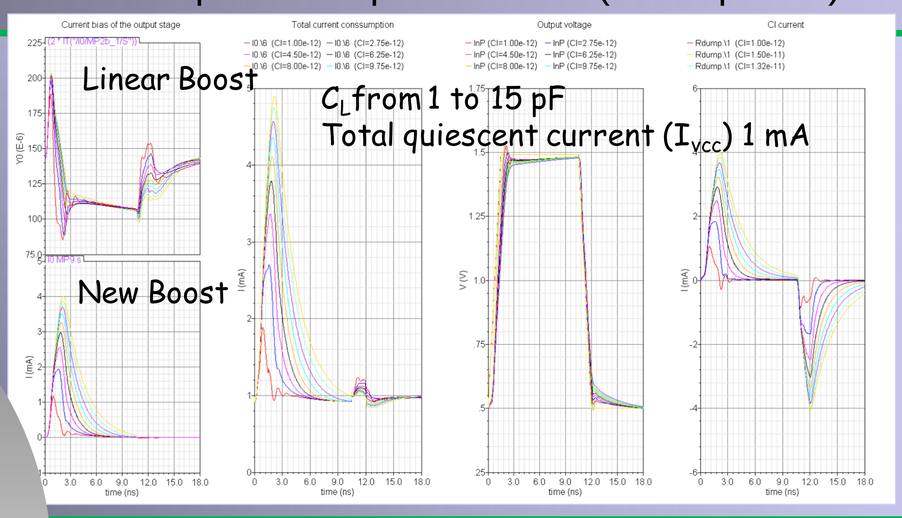


GBW > 6 GHz !



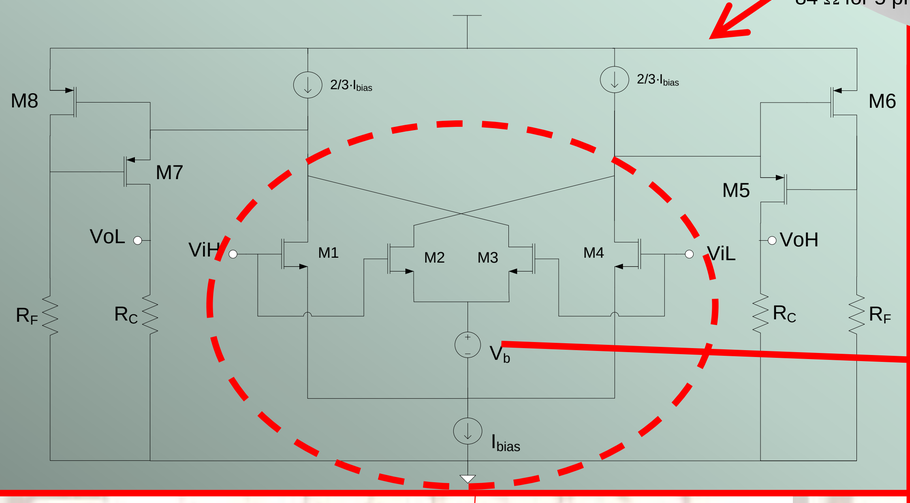
Two current boost circuits: class AB and class B

- Linear class AB moderate (120 uA x 2) boost: SAM chip
- New class B boost current sourcing to load through M7b
  - Follower configuration: when Vi+ increases very fast
    - Non linear transient : Vi- < Vi+ so HZ node ↓↓
  - Negative feedback by Mfb transistor:
    - Copy small signal variation in node HZ to the gate of M7b (Hzf)
    - When HZ node ↓↓ the current in M7b ↑↑ : speed up C_L charging
    - Vi– ↑↑ and HZ node ↑↑
  - Mfb is controlled by a non-linear biasing circuit:
    - VbiasB is such M7b is off at quiescent state
    - When Vi- << Vi+ : M1 takes the diff pair current
      - So M5a(b) current increases subtracting M5bc current
      - Vgs of Mfb increases: Hzf increases: class B enhanced by fb
  - Provides up to 4 mA peak current (total Iq 1 mA)



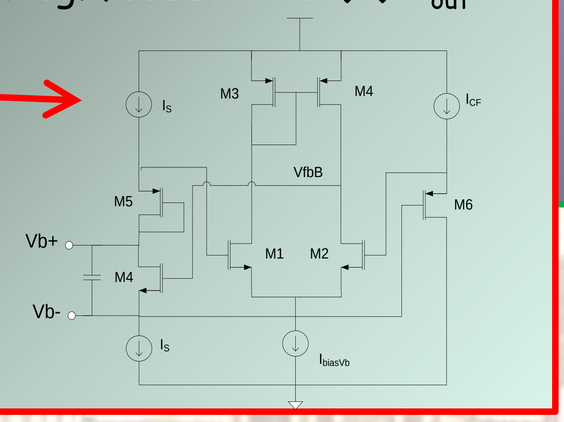
Gain block

- Fully differential 400 MHz BW amplifier
- Voltage gain: 5 to 20 V/V
- Based on HF linearised transconductors



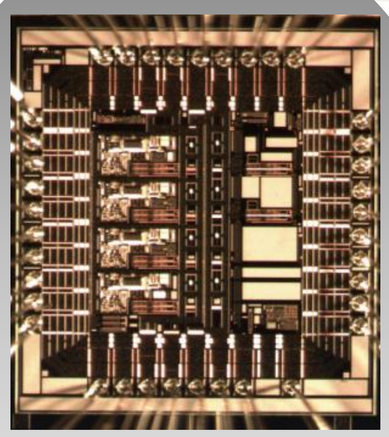
Floating voltage source

- Bias voltage is offset in Vgs of two matched PMOS
- Neg. feedback to ↓↓ r_{out}



Bias-offset cross coupled differential pair

- Linear transcond. $I_{oD} = KV_bV_{iD}$ $\quad K = \frac{1}{2}\mu C_{ox}\frac{W}{L}$
  - First order:
    - Linear using square law MOS: saturation $\longrightarrow |V_{in}| \le \sqrt{\frac{I_{bias}}{K} - \frac{3}{4}V_b^2} - \frac{V_b}{2}$
  - Tuneable gain
- Second order effects on linearity
  - Channel length modulation $\longrightarrow$ Control V_{DS} variations
  - Mismatch $\longrightarrow$ Large WL and common centroid
  - Mobility reduction $\longrightarrow$ Scaling M1-4 vs M2-3 (for a given G_m)
  - Body effect $\longrightarrow$ Cannot use PMOS (large K needed)

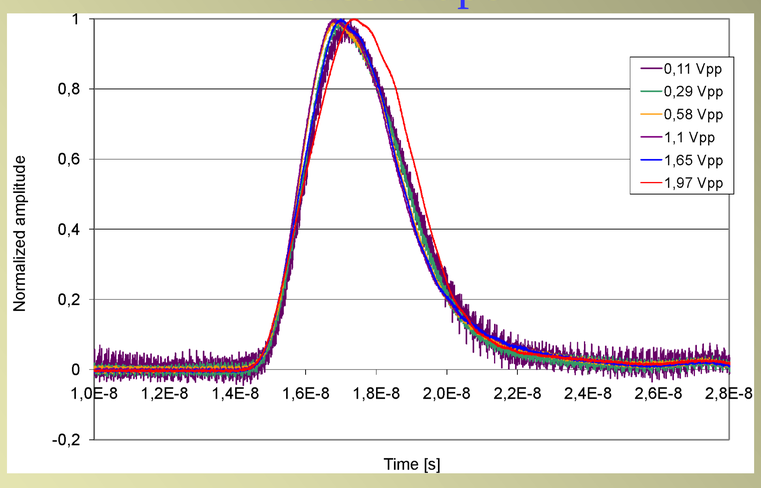


ACTA3
4 ch
CMOS
0.35um
AMS
3 mm²

Measurement results

Parameter	Value	Units	Comments
Gain	5 to 20	V/V	Tuneable (through I_{cf} and I_{bias})
BW	400	MHz	C_L=3-4 pF. Extrapolated from B01
Slew Rate	1 to 1.5	V/ns	For 3-4 pF load (tuneable OpAmp bias)
Linearity (VoD<1Vpp)	< 1	%	Depends on I_{cf} and I_{bias}
Linearity (VoD<2Vpp)	< 3	%	Depends on I_{cf} and I_{bias}
Input ref. noise (e_n)	< 3		For gain > 5
DC offset (output)	0 to 1.5	V	Tuneable by control current (I_{bof})
Gain Temp. Coef. (TC)	0.06	%/C	After temp. compensation via TC of I_{cf}
Power consumption	20 – 30	mW	

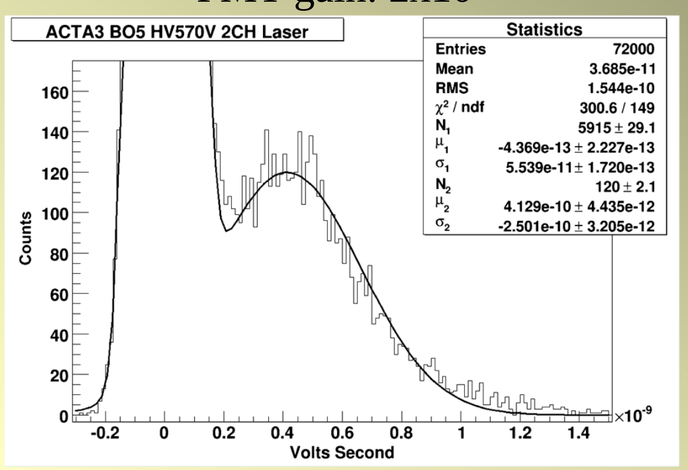
Pulse shape



Linearity

Single photoelectron spectra

PMT gain: $2x10^5$



Frequency response