POLITECNICO MILANO 1863

ELECTRONIC SYSTEMS

2021-22 academic year

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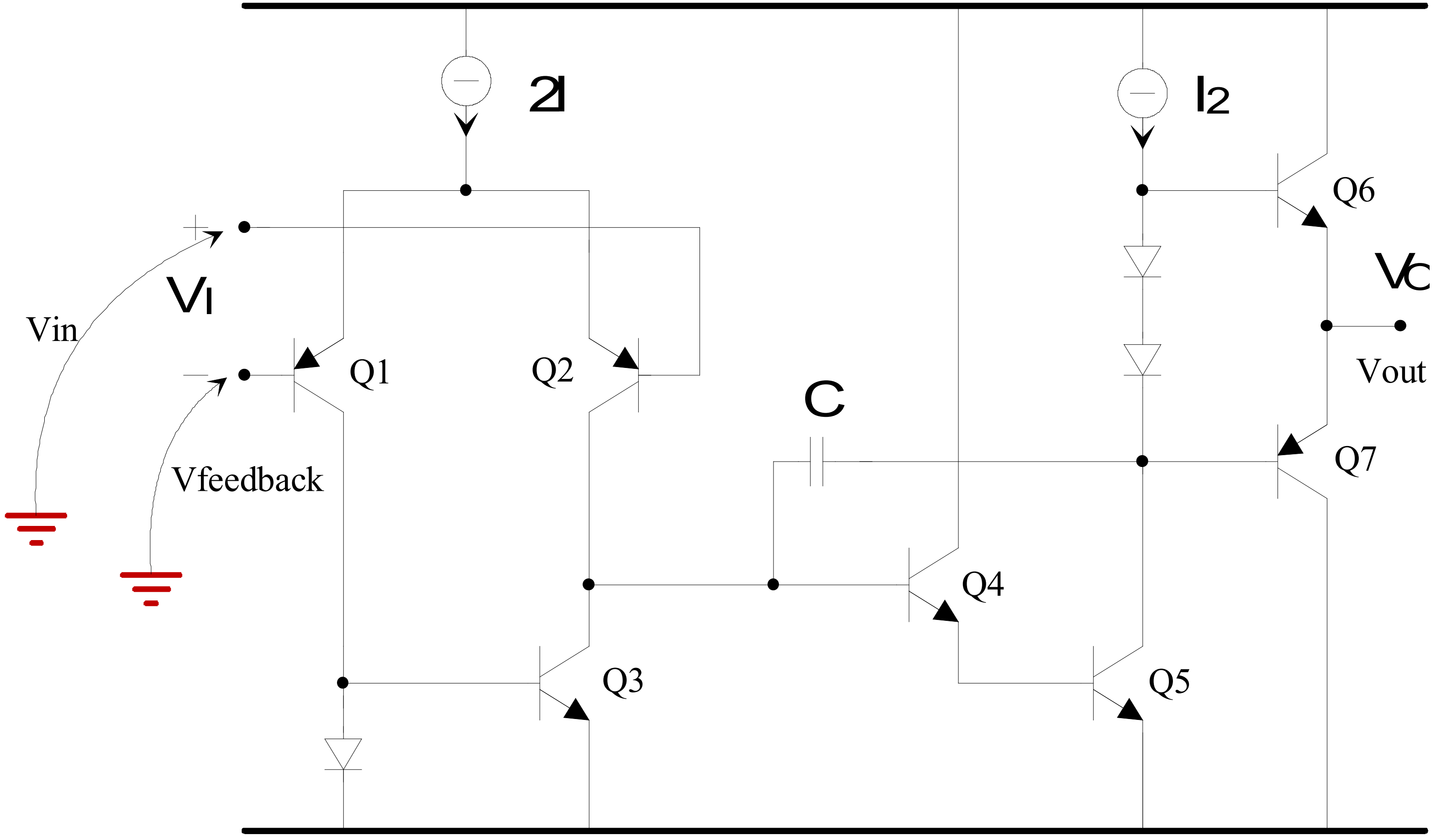
Summary

- Principle of current feedback
- Comparisons with voltage feedback
- Modeling
- Internal schematics
- Further improvements

Voltage Mode (VOA)

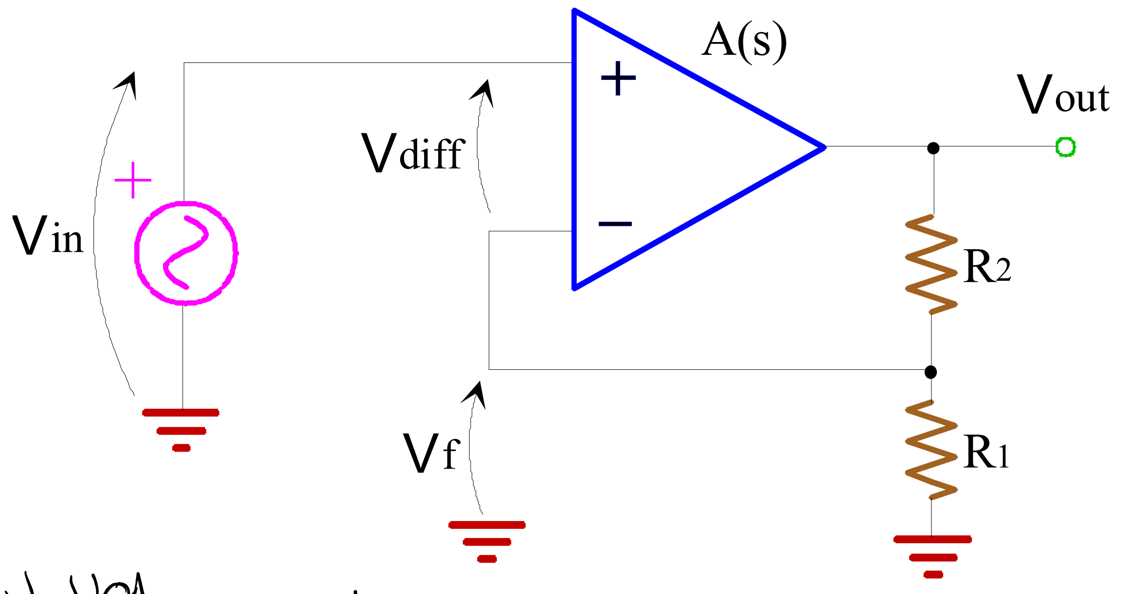


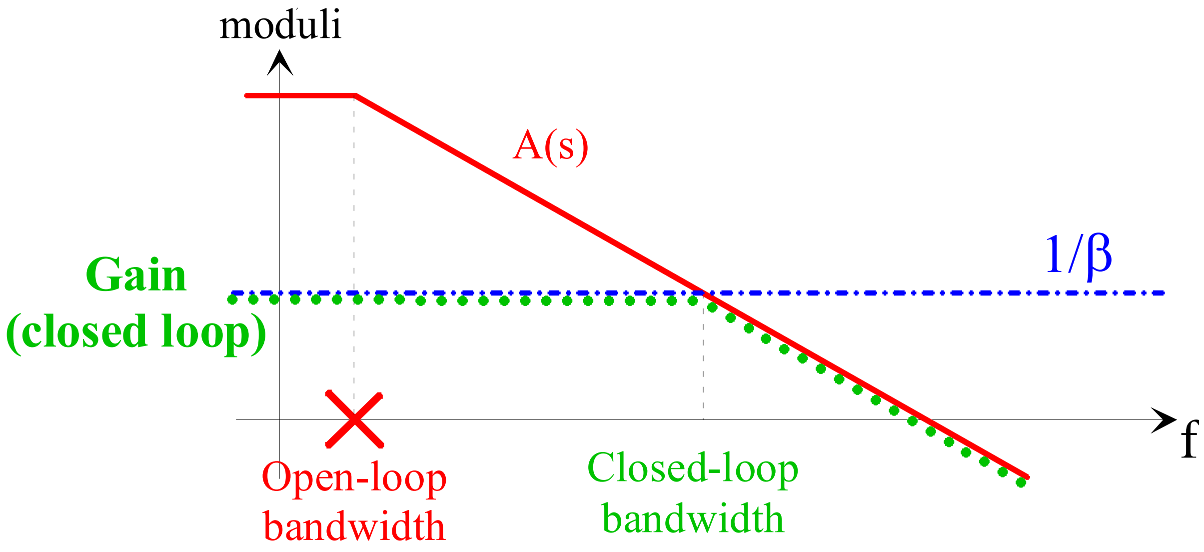
Requirements:

voltage-driven inputs → high impedance inputs

voltage output → low-impedance output

Voltage Mode (VOA)





Con il VOA se voglio aumentare il guadagno la banda cala perché il guadagno è strettamente dipendente da 1/β. Se aumento il guadagno di 10, allora f* scende di un valore 10.

Performances:

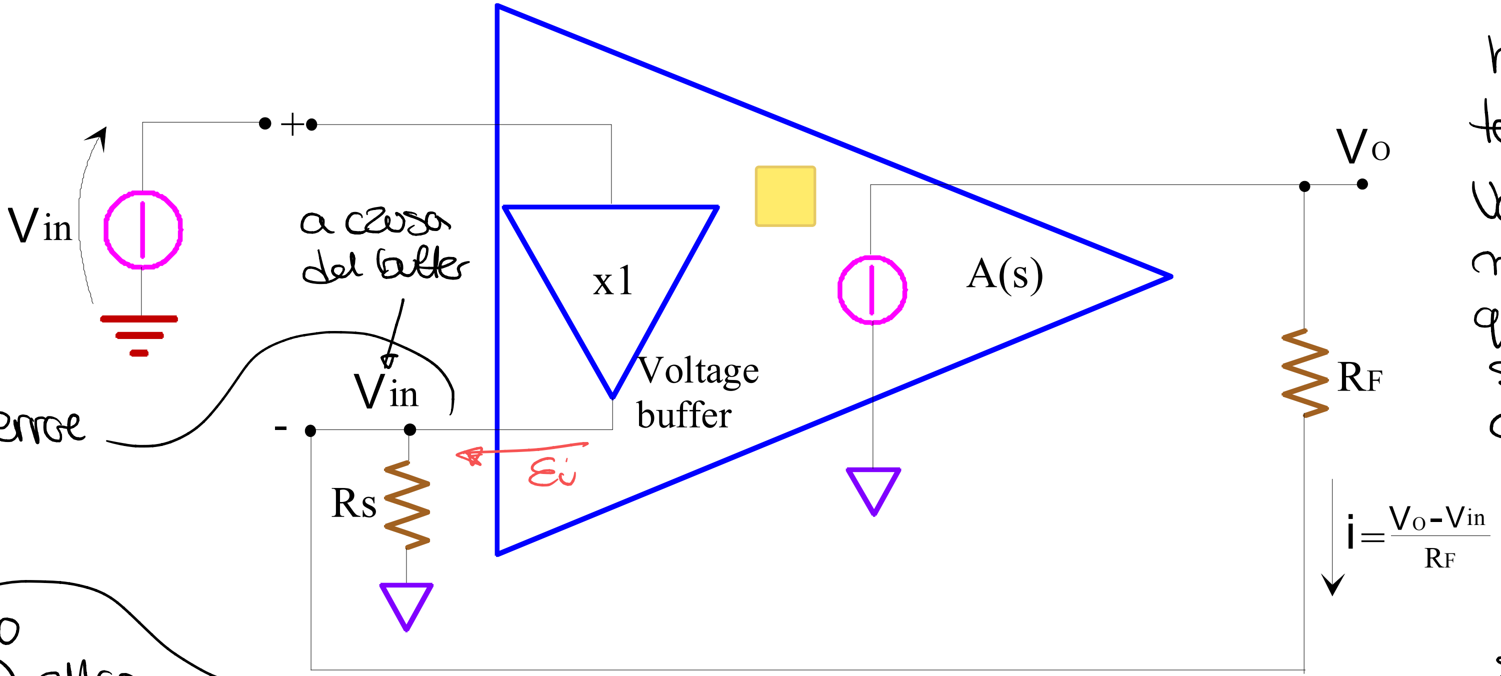
-20dB/dec slope

constant GBWP (hence trade-off between gain and bandwidth)

limited SR (tens of V/μs)

strict relationships among f_0 I_{tail} C_{comp} SR (again trade-off)

Current Feedback (CFA)

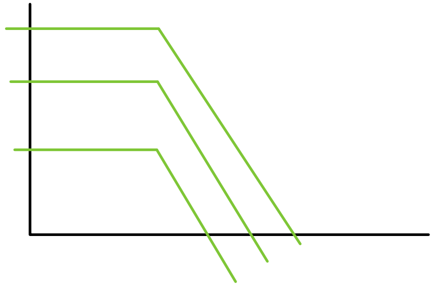


Qui in uscita ho un errore di corrente

ho che A(s) tenta di portare Vo ad una tensione molto alta questo fa sì che si crei una corrente in contrapposizione a $E_i = V_{in}/R_S$ e farà sì che si annulli.

Se $E_i = \emptyset$ noi sappiamo che $A(s) = R_o E_i$ e quindi va al valore che mi fa sì che $E_i = i$ in modo che si annullino.

Se cambio il guadagno cambiando solo Rg(Rs) allora posso avere la struttura che



Requirements:

one high-impedance input (hence voltage-driven input)

one low-impedance input (hence input-current, i.e. Acting as an output)

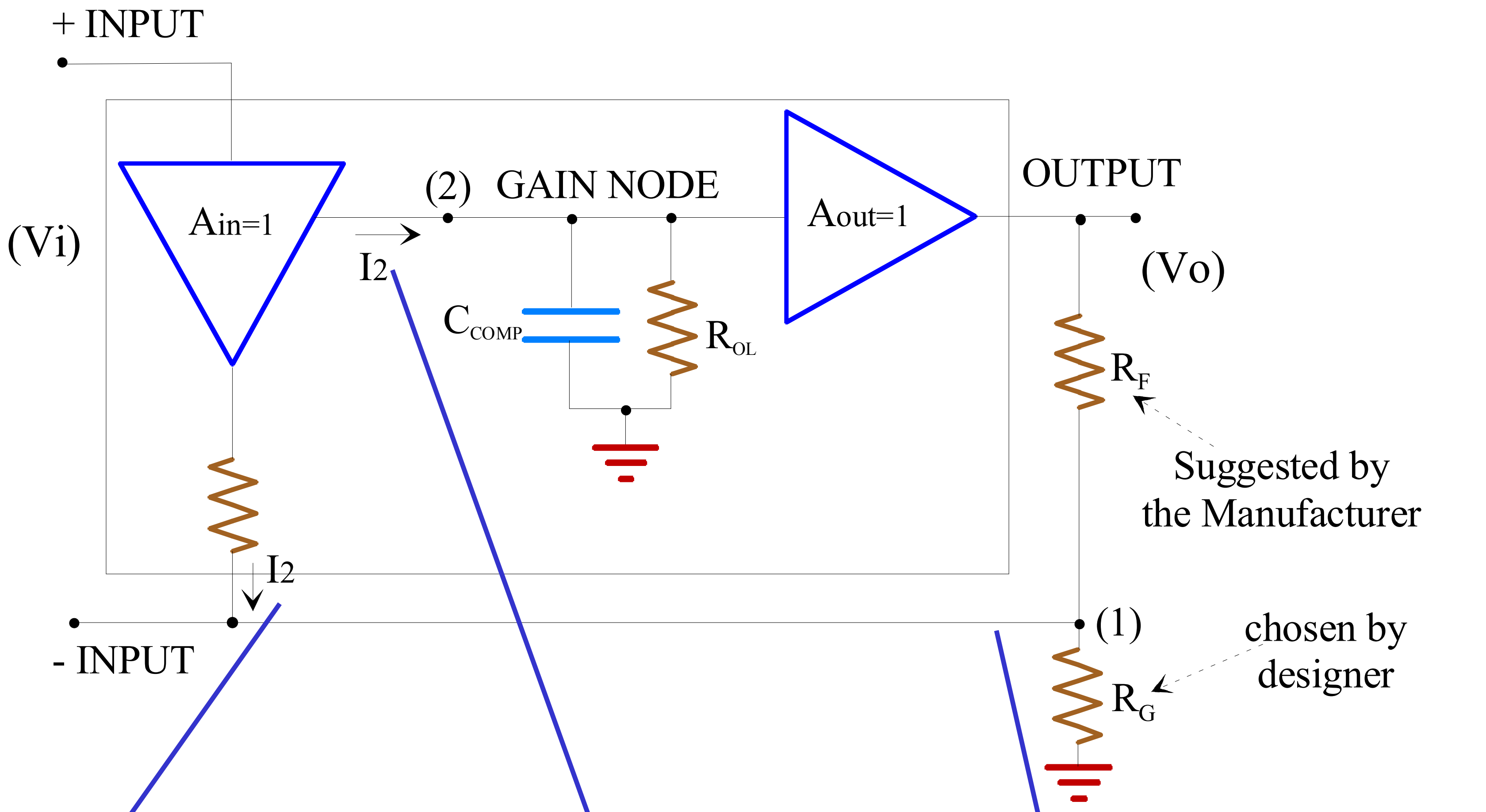
voltage output (proportional to the input current)

non devo cambiare RF perché il polo dipende da lei.

$$G_c = 1 + \frac{R_F}{R_S}$$

It looks identical to VOA, but completely different feedback action

CFA

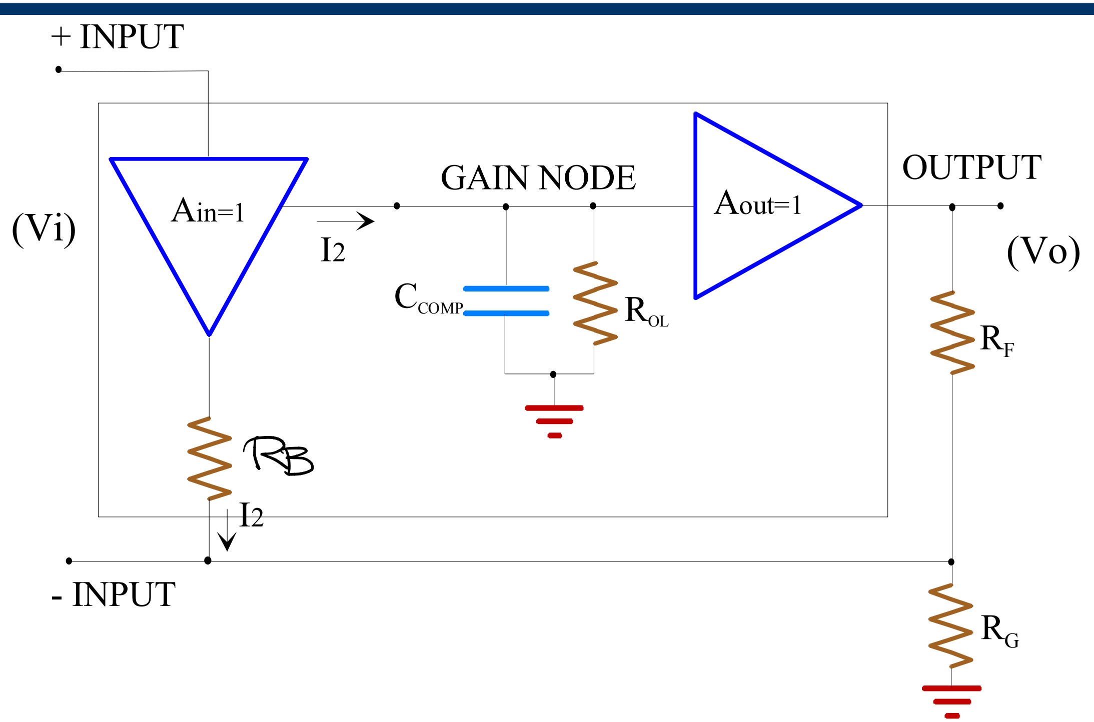


$$I_2 = \frac{Vin - V_1}{R_B} = V_1 \cdot \left(\frac{1}{R_G} + \frac{1}{R_F} \right) - \frac{Vout}{R_F}$$

$$V_2 = I_2 \cdot \frac{R_{OL}}{1 + sR_{OL} \cdot C_{comp}}$$

$$\frac{V_1}{R_G} + \frac{V_1 - V_O}{R_F} + \frac{V_1 - V_{in}}{R_B} = 0$$

CFA



Closed-loop Gain:

$$\frac{Vout}{Vin}=\frac{1+\frac{R_F}{R_G}}{\left(1+\frac{R_F+\left(1+\frac{R_F}{R_G}\right)\cdot R_B}{R_{OL}\cdot A_{out}}\right)\cdot\left[1+s\,\frac{\left[R_F+\left(1+\frac{R_F}{R_G}\right)\cdot R_B\right]}{A_{out}+\frac{R_F+\left(1+\frac{R_F}{R_G}\right)\cdot R_B}{R_{OL}}}\cdot C_{comp}\right]}$$

è un casino di formula
dobbiamo fare due semplificazioni
$R_G >> R_B$

CFA: bandwidth

Bandwidth: $$f_{pole} \cong \frac{A_{out}}{2\pi\left[R_F + \left(1+\frac{R_F}{R_G}\right)\cdot R_B\right]\cdot C_{comp}}$$

Per noi RG>>RB, allora si può approssimare con

For low gain ($R_B << \frac{R_F \cdot R_G}{R_F + R_G} = R_F \parallel R_G$) we get $$\boxed{f_{pole} \cong \frac{1}{2\pi \cdot R_F \cdot C_{comp}}}$$

Bandwidth depends only on R_F, not on R_G, **hence *NOT ON GAIN* !**

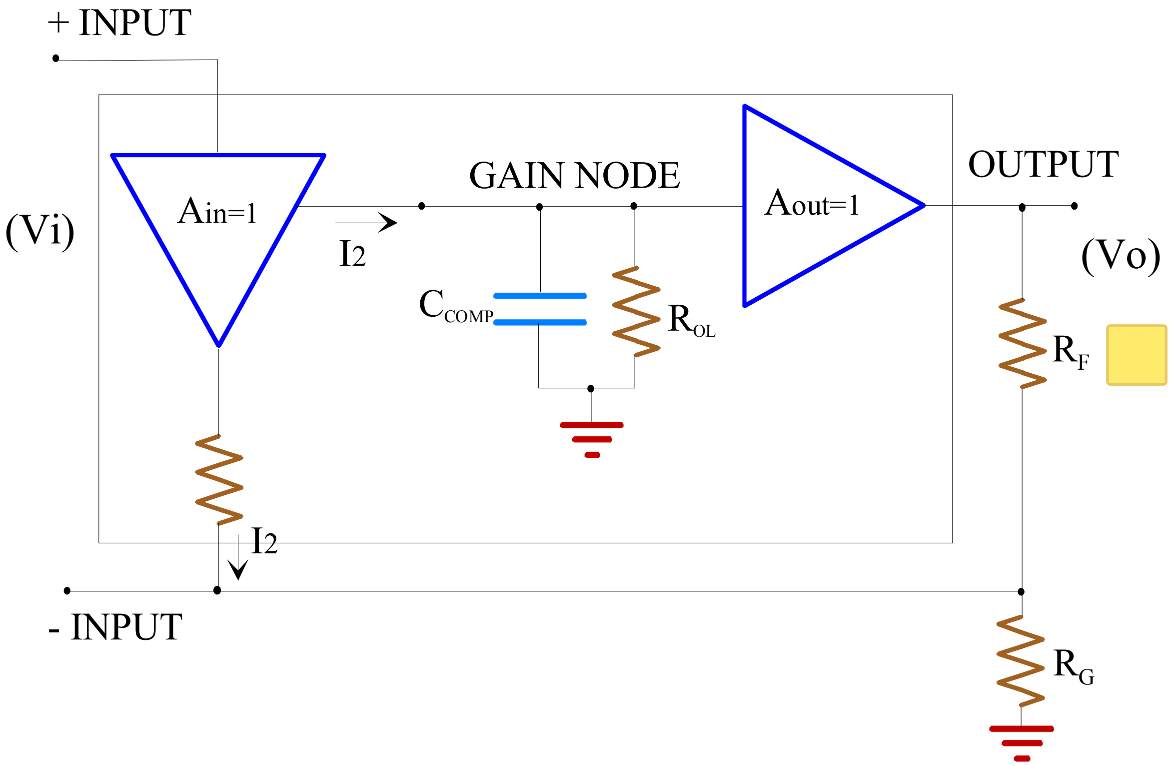
Instead for high gain (>50) we get $$GBWP = \frac{A_{out}}{2\pi R_B \cdot C_{comp}}$$

As for VOA, again trade-off Gain &Bandwidth (i.e. constant GBWP)

CFA: bandwidth

Let's study the feedback in a smarted way...

...same result at the end!



Il polo a circuito chiuso è quello a circuito aperto che sarebbe quello avuto (RoCcomp) moltiplicato per (1-Gloop)

With open-loop: $pole_{openloop} \approx \dfrac{-1}{C_{comp} \cdot R_{OL}}$

$$G_{loop} \approx -R_{OL} \cdot A_{out} \cdot \frac{1}{R_B + R_F} \approx -\frac{R_{OL}}{R_F}$$

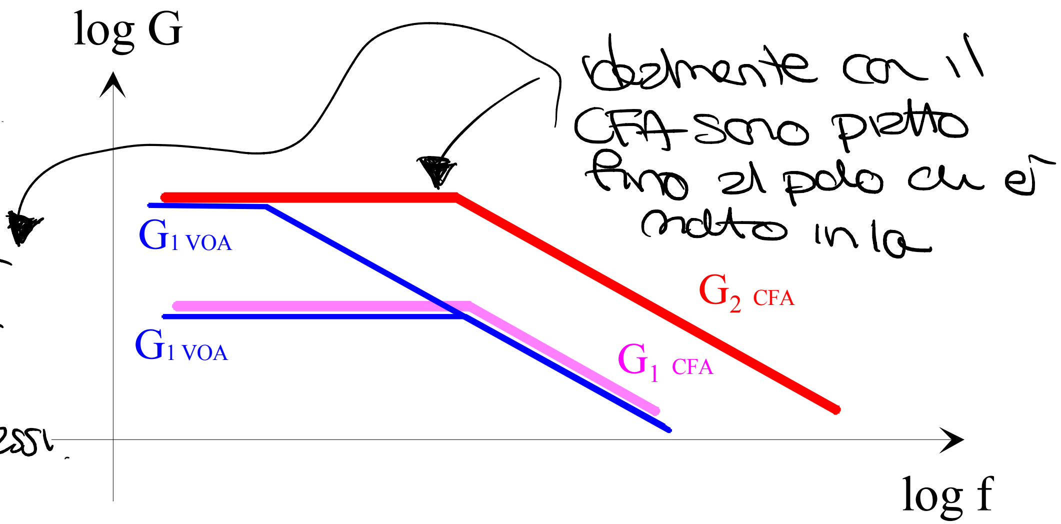
… hence, when loop is closed:

$$pole_{closedloop} = pole_{openloop} \cdot \left(1 - G_{loop}\right) \approx \frac{-1}{C_{comp} \cdot R_{OL}} \cdot \frac{R_{OL}}{R_F} = \frac{-1}{C_{comp} \cdot R_F}$$

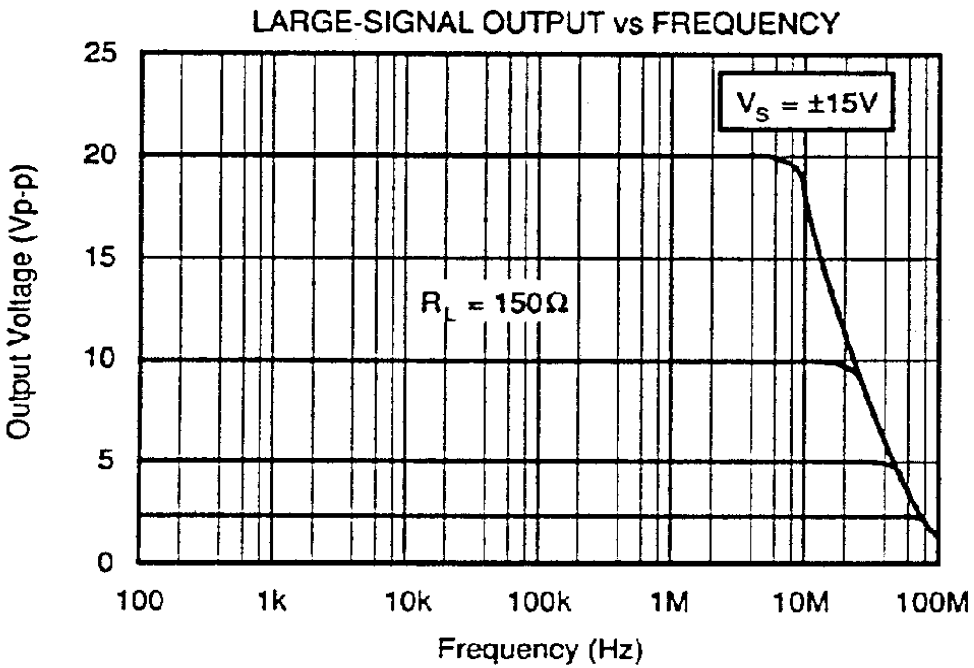
CFA: bandwidth

In conclusion, at low gains...

Questo è vero solo per guadagni abbastanza bassi.

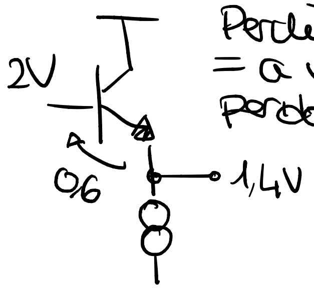


Instead at high gains...



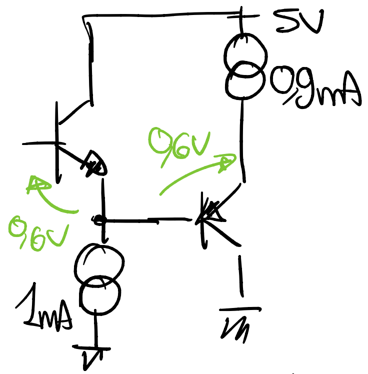
CFA: a real architecture

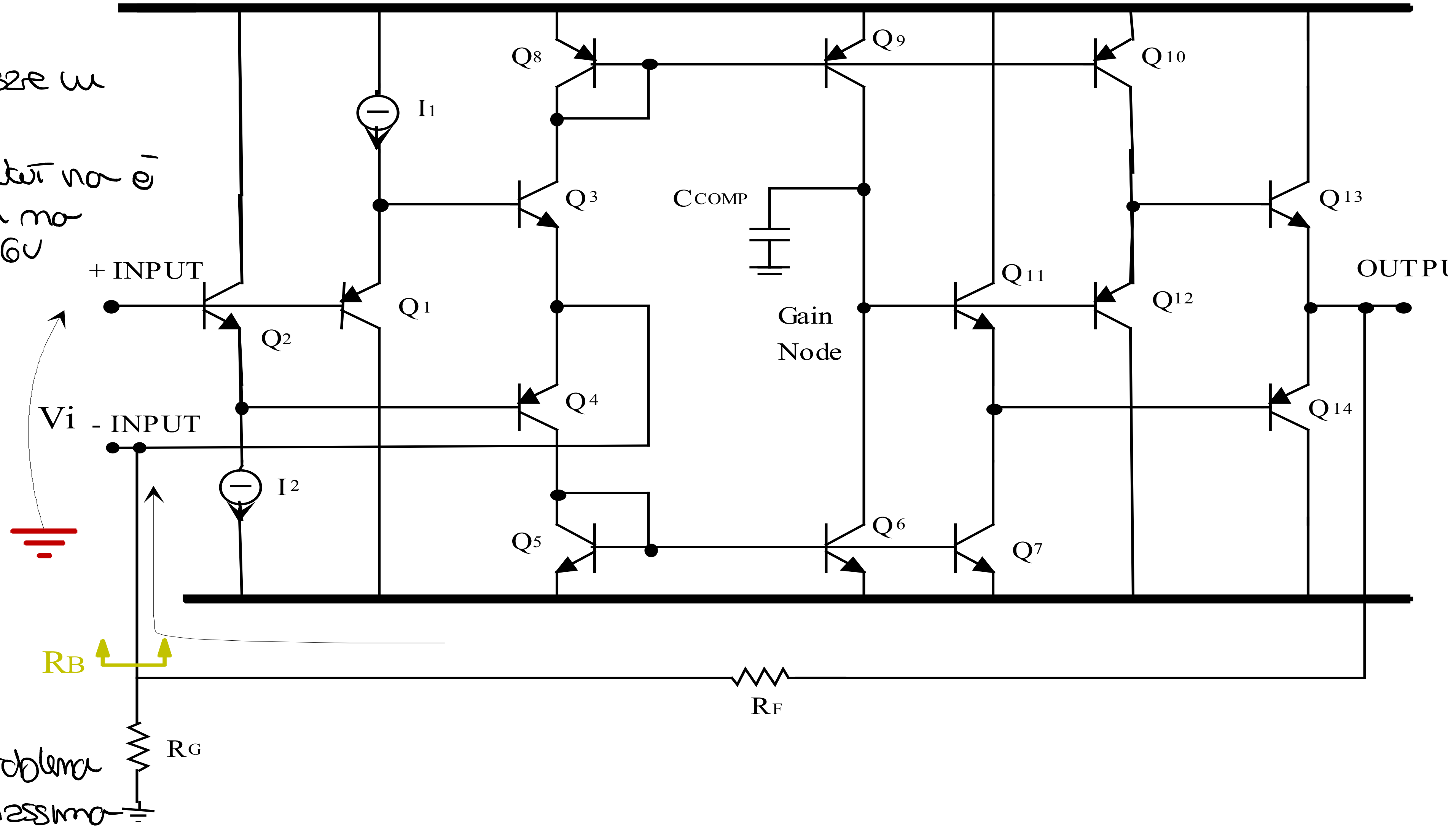
Non possiamo usare un buffer così



Perché Vout non è = a Vin ma perdo 0,6V

Potremmo usare una struttura tipo



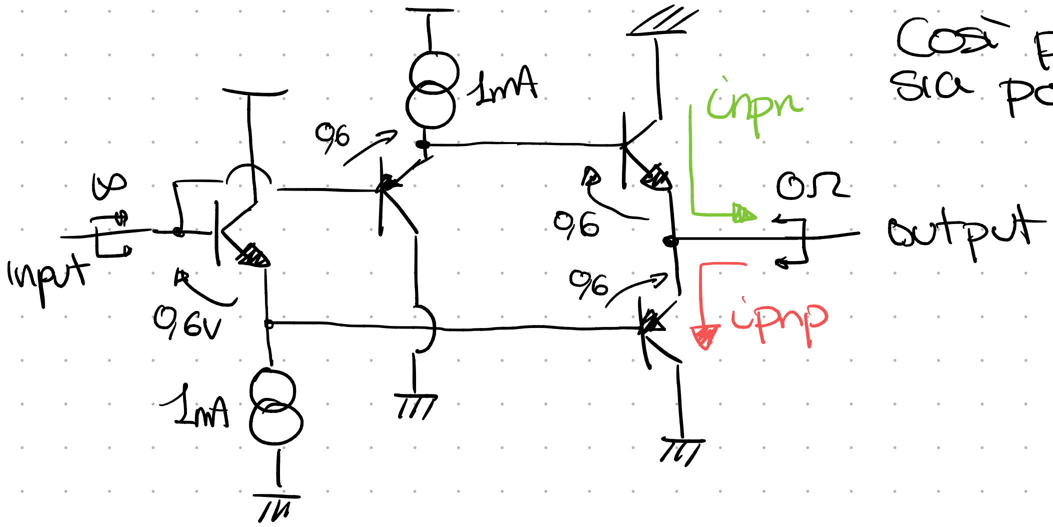


ho Vout=Vin, il problema è che la corrente massima sull out è 0,9mA altrimenti il PNP si spegne

Complementar **npn**+**pnp** darlington configurations, hence better **SR**...

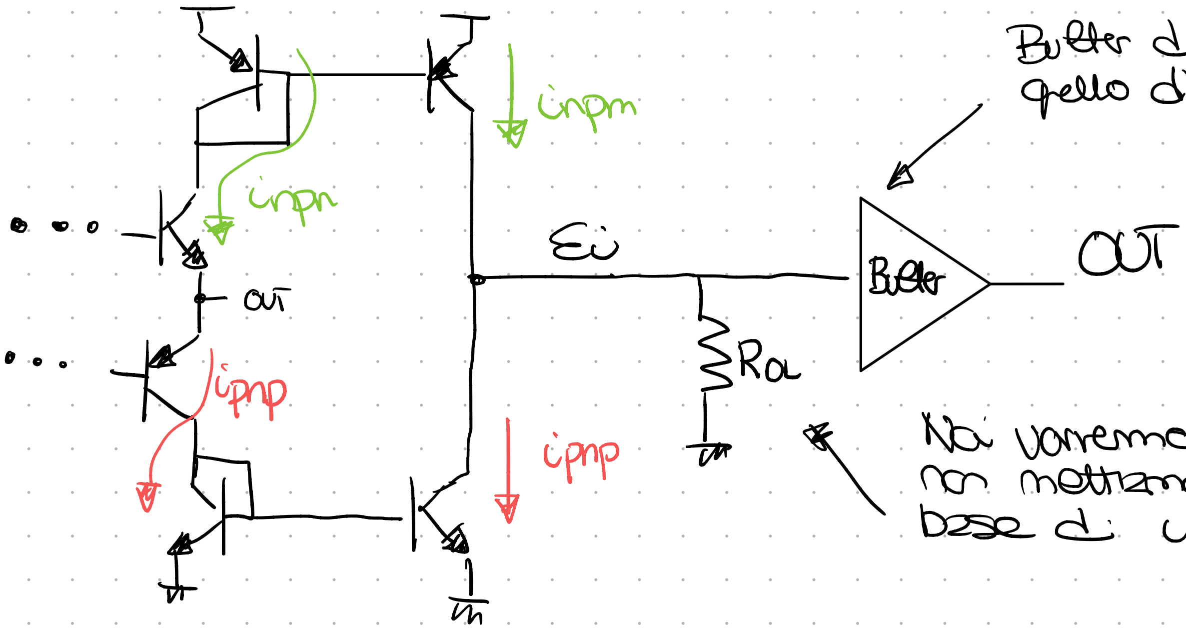
but problems of matching, hence higher **offset voltage**

Duplichiamo il circuito di prima per avere un buon buffer



Così posso portare corrente in uscita sia positiva che negativa

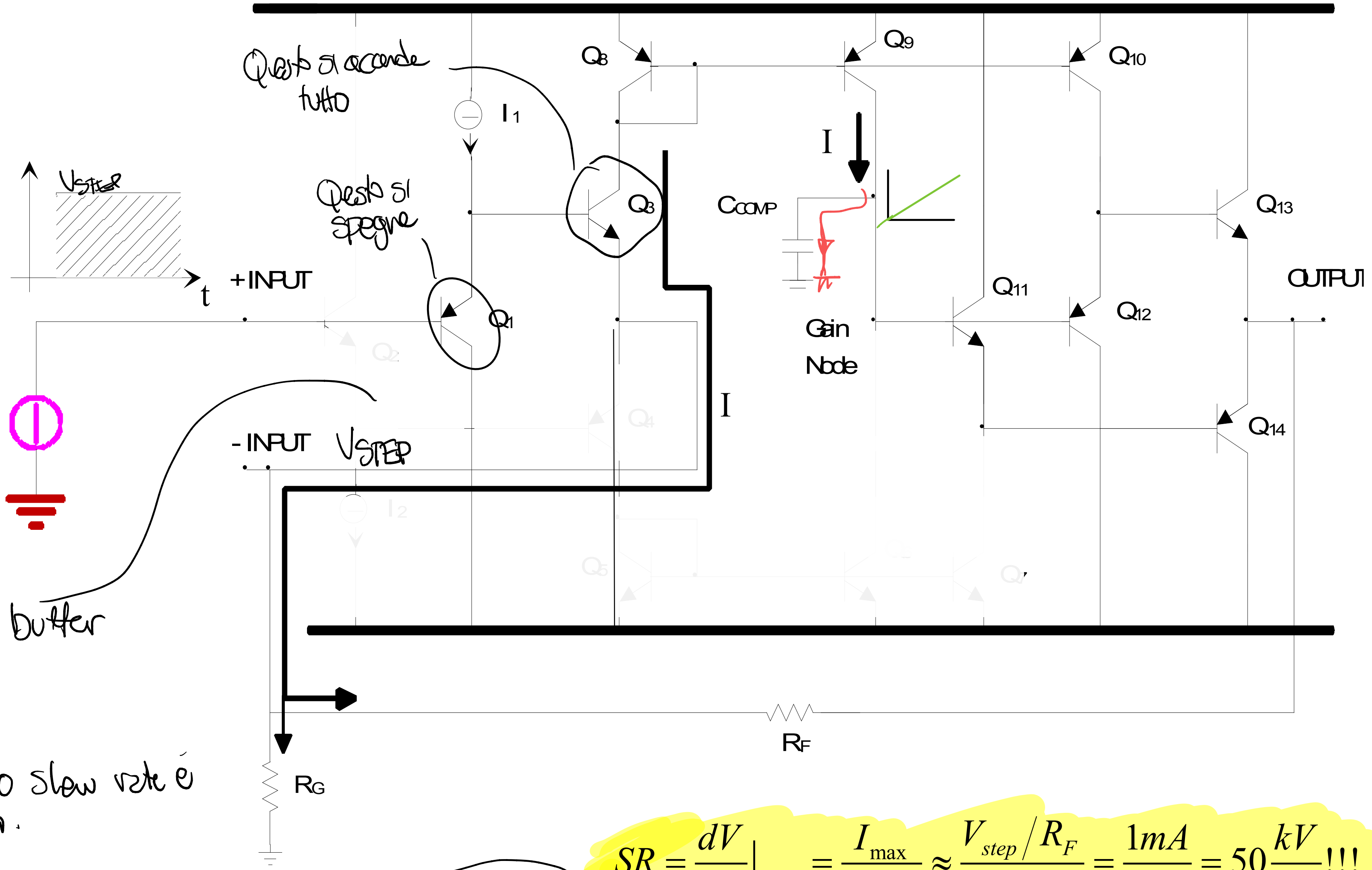
Noi vogliamo capire la corrente data dai mos npn e pnp



Buffer di uscita può essere uguale a quello d'ingresso.

Noi vorremo $R_a = \infty$ perciò semplicemente non mettiamo una R_a ed entriamo sulla base di un transistor

CFA: transient response… SlewRate



Xè ho un buffer

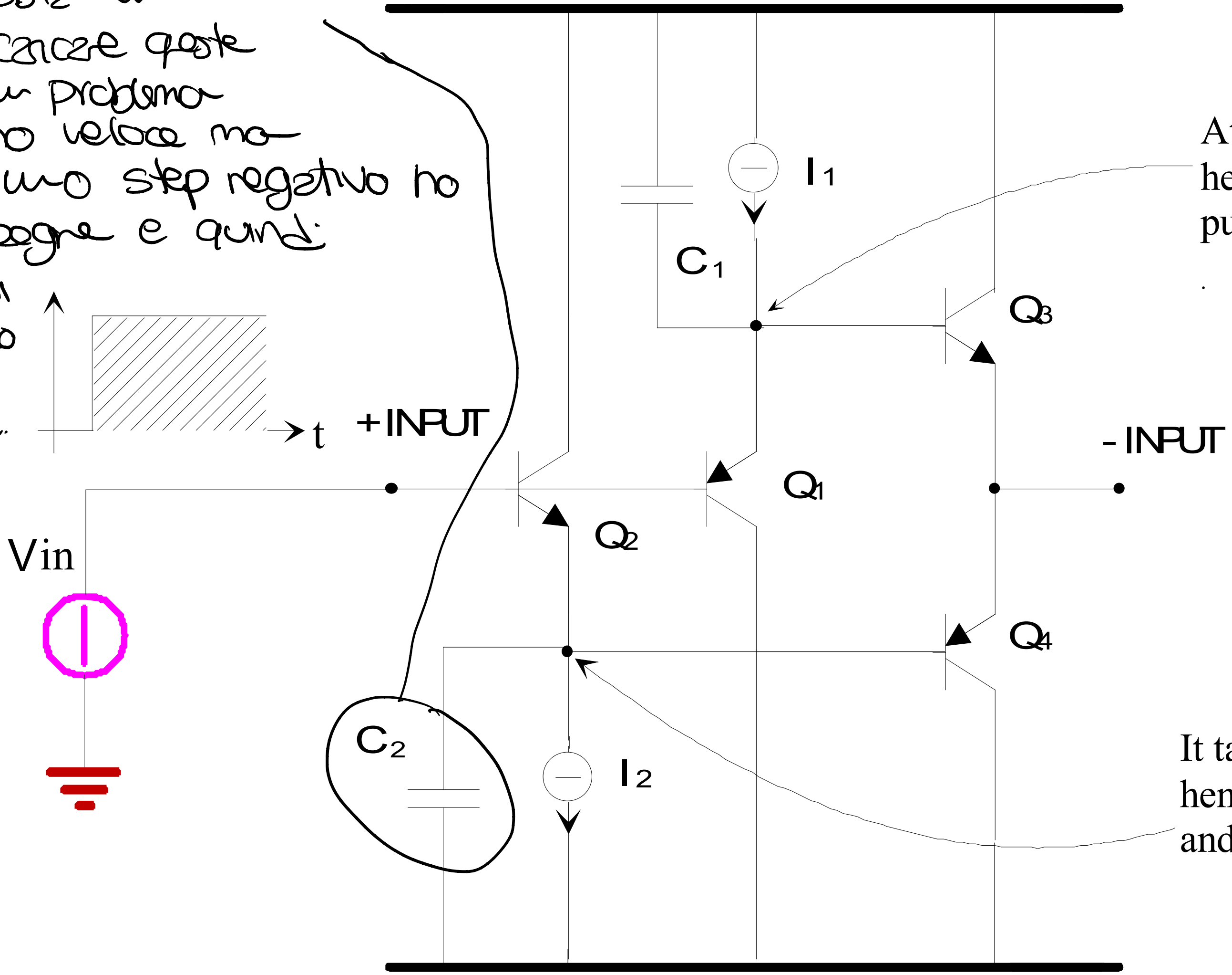
Nel CFA lo slew rate è molto alto.

$$SR = \left.\frac{dV}{dt}\right|_{max} = \frac{I_{max}}{C_{comp}} \approx \frac{V_{step}/R_F}{C_{comp}} = \frac{1mA}{1pF} = 50\frac{kV}{\mu s}!!!$$

CFA: transient response

Indeed there are second-order effects, which degrade SR

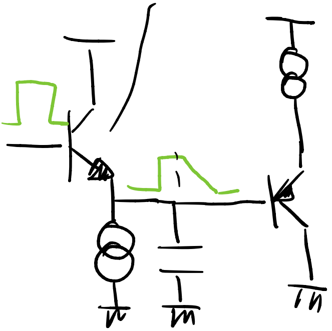
Ho delle capacità parassite che fanno sì che abbia un transitorio. Per caricare queste capacità non è un problema perché si caricano veloce ma quando abbiamo uno step negativo ho che il BJT si spegne e quindi la capacità si può scaricare solo sulla r parassita del gen di corrente.



At first it stays charged hence Q_1 goes off instad of pulling up the node

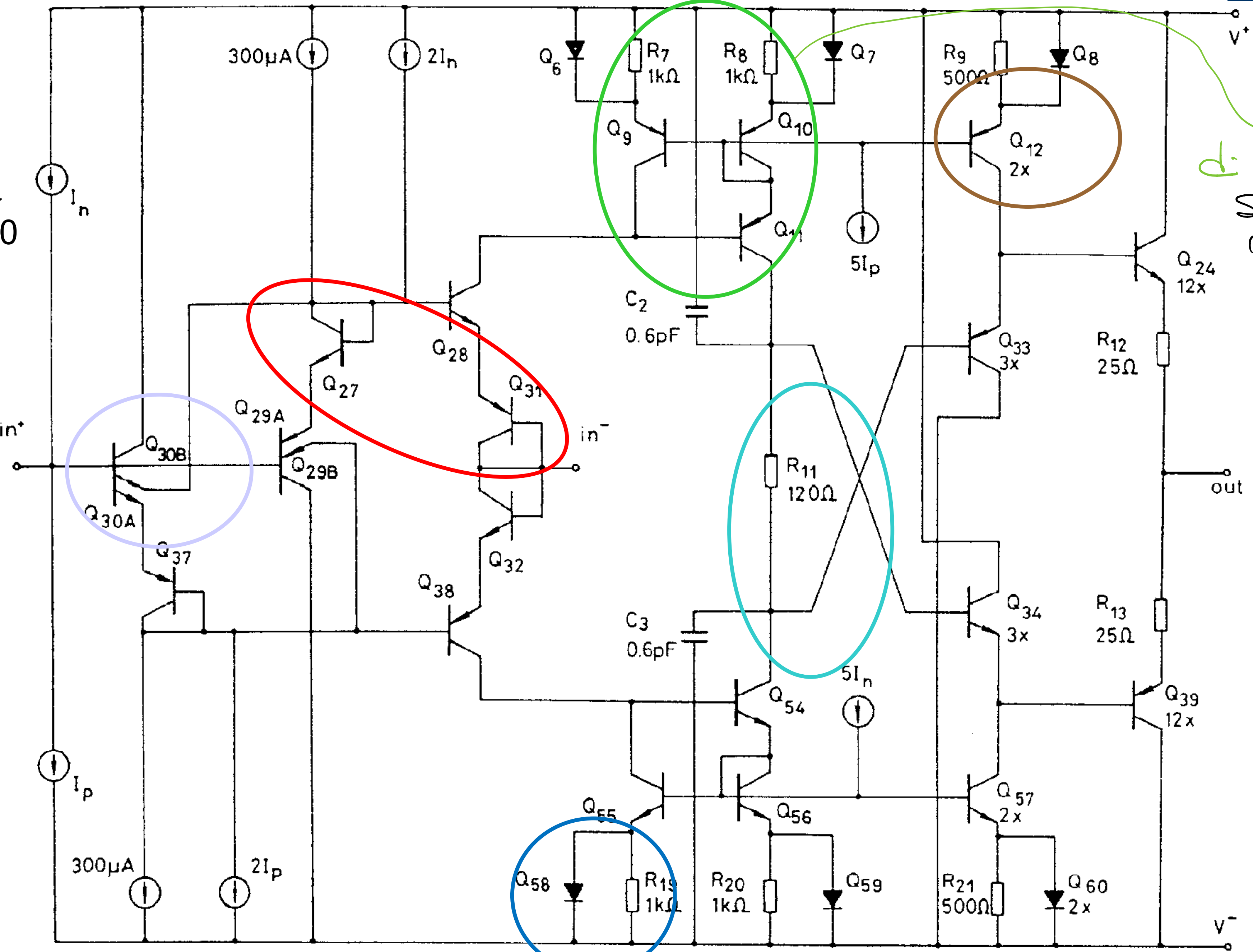
It takes time to be charged up hence the node stays low and Q4 keeps sinking current

si spegne perché $V_{in} = V_B < V_E$



Questa è un altra architettura e migliora tutto.

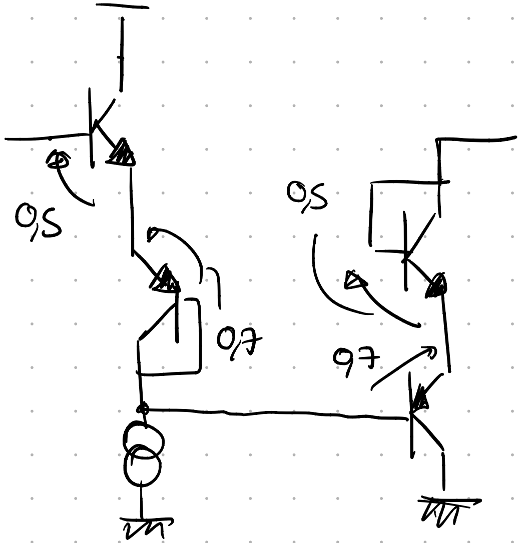
OPA260



Specchio di Widlar

Serve per migliorare il trasferimento

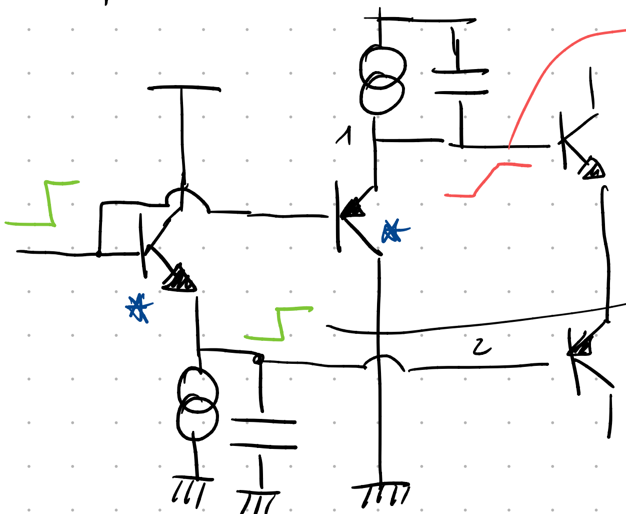
Posso fare una cosa del tipo per compensare



Faccio 2 transdiodi in modo che se V_T drifta in modo diverso tra npn e pnp ho che i 2 stadi sono comunque compensati

(Bisogna poi fare la stessa cosa con l'altra parte del circuito buffer)

Altro problema che abbiamo è che



Al contrario qui ho che il segnale è molto lento

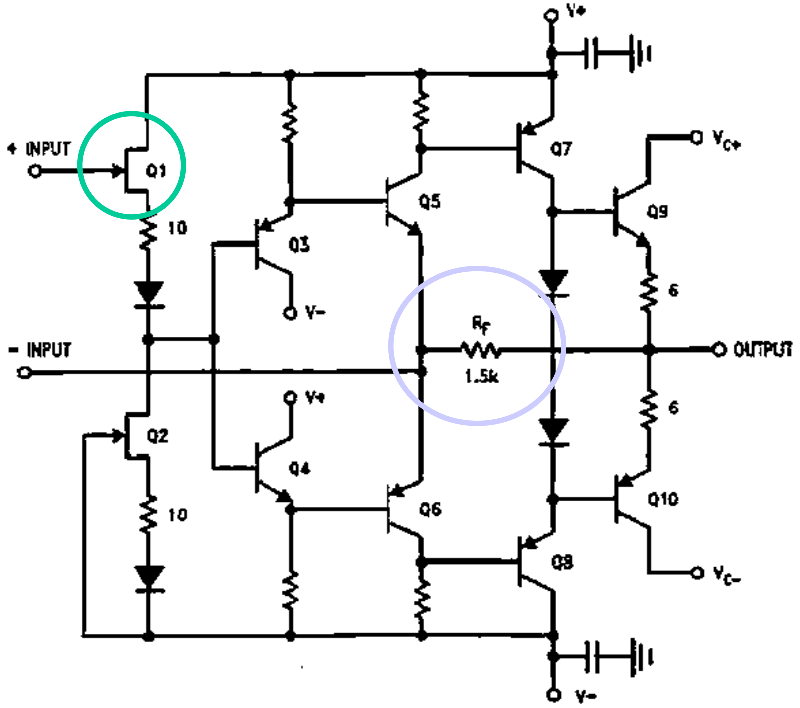
Sono felice perché qui ho che lo step è veloce

Per risolvere questo uso un transistor multiemettitore

Al posto di questi 2 transistor * metto i 2 multiemettitore che collego a 1 e 2. questa parte del transistor è sempre off tranne quando ho un grandissimo step in ingresso

CFA: other architectures

Data-sheet LH4117:



Application-note:

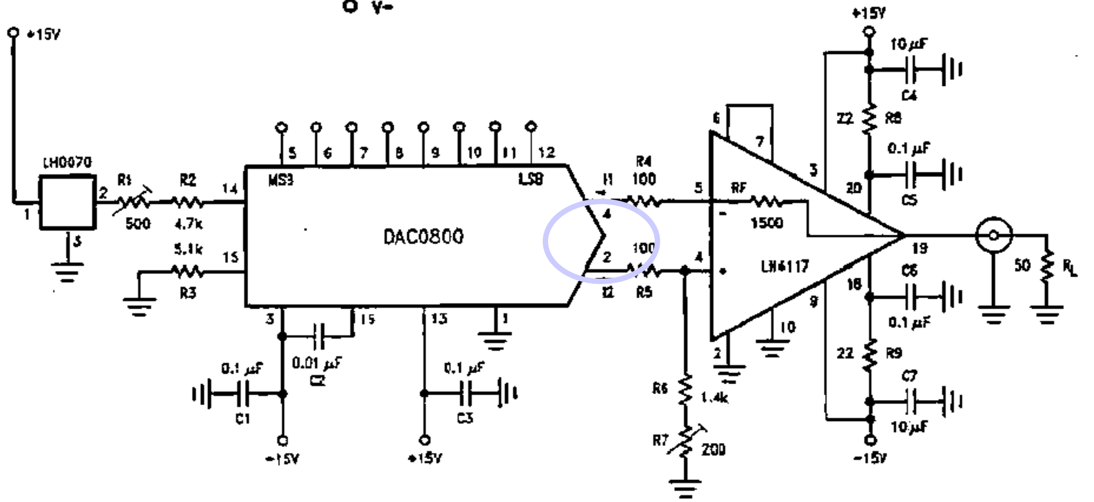
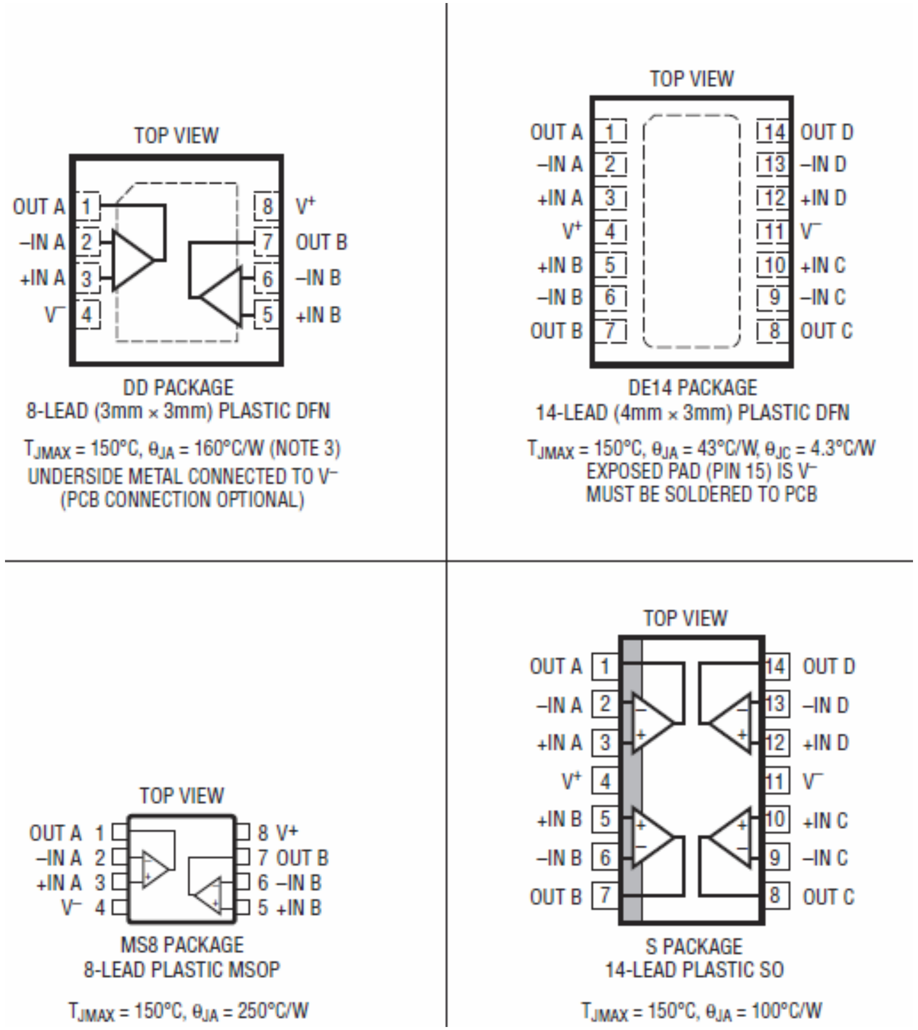


FIGURE 7. Fast Current-to-Voltage Current Mode DAC Amplifier

Data-sheet LT1395:



LINEAR TECHNOLOGY

LT1395/LT1396/LT1397

Single/Dual/Quad 400MHz Current Feedback Amplifier

FEATURES

- **400MHz Bandwidth on ±5V (A_V = 1)**
- **350MHz Bandwidth on ±5V (A_V = 2, –1)**
- **0.1dB Gain Flatness: 100MHz (A_V = 1, 2 and –1)**
- High Slew Rate: 800V/µs
- Wide Supply Range: ±2V(4V) to ±6V(12V)
- 80mA Output Current
- Low Supply Current: 4.6mA/Amplifier
- LT1395: SO-8, TSOT23-5 and TSOT23-6 Packages
  LT1396: SO-8, MSOP and Tiny 3mm × 3mm × 0.75mm DFN-8 Packages
  LT1397: SO-14, SSOP-16 and Tiny 4mm × 3mm × 0.75mm DFN-14 Packages
- Low Profile (1mm) ThinSOT™ Package

APPLICATIONS

- Cable Drivers
- Video Amplifiers
- MUX Amplifiers
- High Speed Portable Equipment
- IF Amplifiers

DESCRIPTION

The LT®1395/LT1396/LT1397 are single/dual/quad 400MHz current feedback amplifiers with an 800V/µs slew rate and the ability to drive up to 80mA of output current.

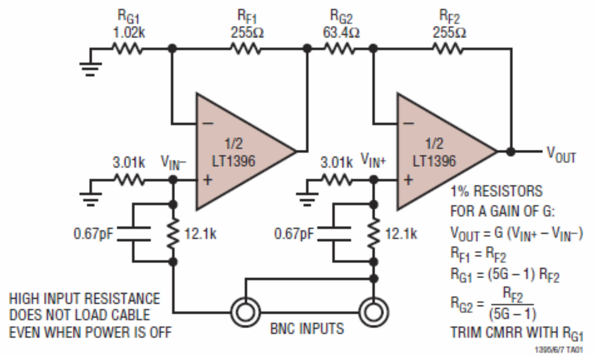
The LT1395/LT1396/LT1397 operate on all supplies from a single 4V to ±6V. At ±5V, they draw 4.6mA of supply current per amplifier. The LT1395CS6 also adds a shutdown pin. When disabled, the LT1395CS6 draws virtually zero supply current and its output becomes high impedance. The LT1395CS6 will turn on in only 30ns and turn off in 40ns, making it ideal in spread spectrum and portable equipment applications.

For space limited applications, the LT1395 is available in TSOT-23 packages, the LT1396 is available in a tiny 3mm × 3mm × 0.75mm dual fine pitch leadless DFN package, and the LT1397 is available in a tiny 4mm × 3mm × 0.75mm DFN package.

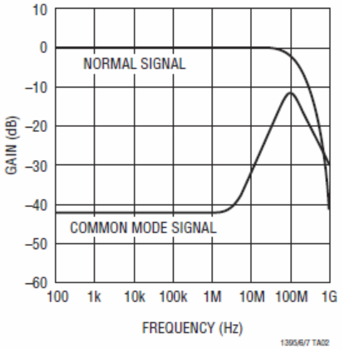
The LT1395/LT1396/LT1397 are manufactured on Linear Technology's proprietary complementary bipolar process. They have standard single/dual/quad pinouts and they are optimized for use on supply voltages of ±5V.

TYPICAL APPLICATION

Unity-Gain Video Loop-Through Amplifier



Loop-Through Amplifier Frequency Response



CFA

Data-sheet LT1395:

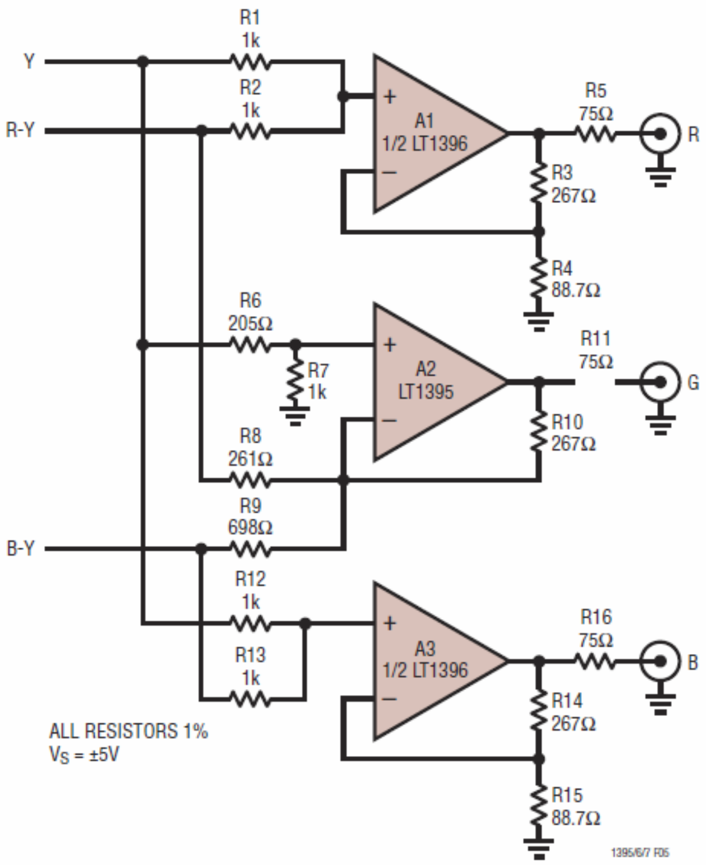
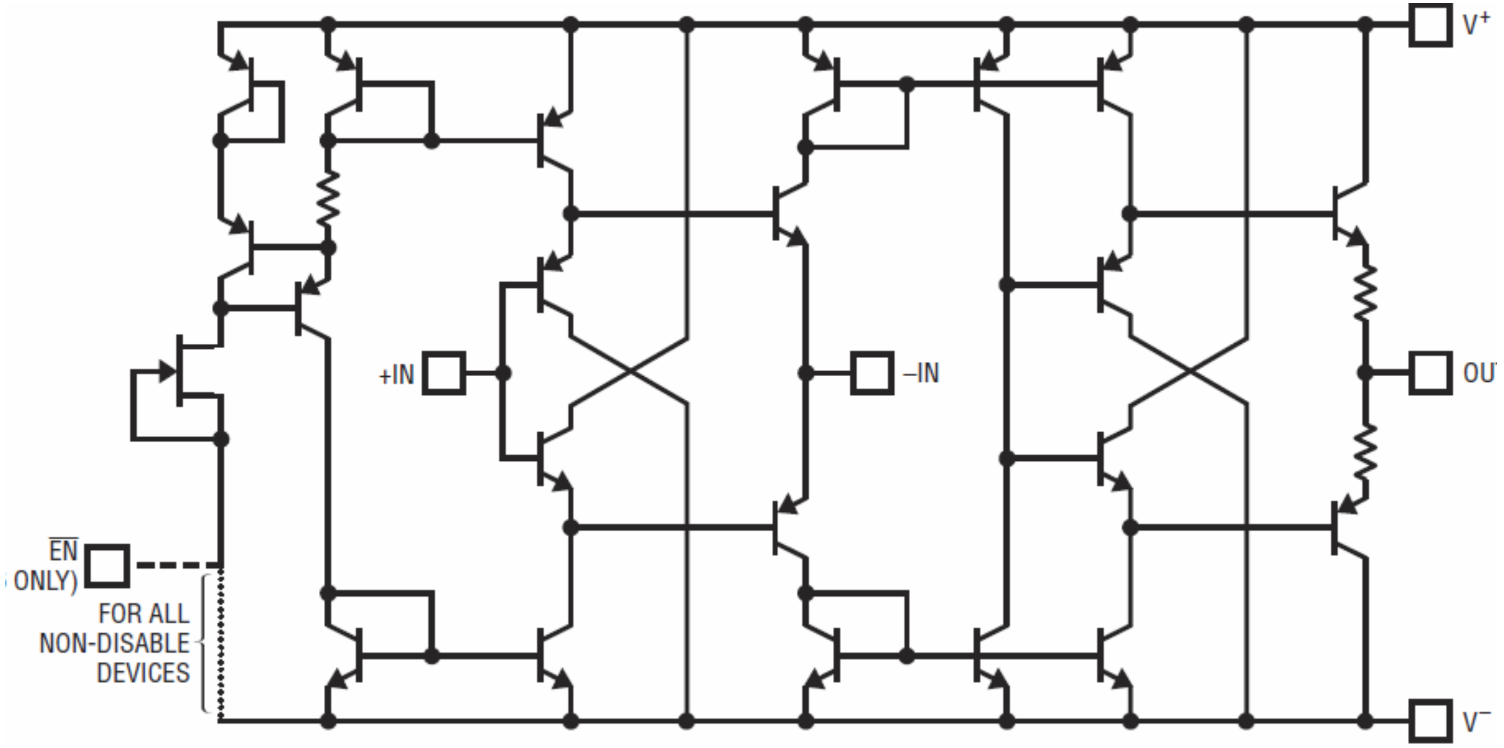


Figure 5. Buffered Color-Difference to RGB Matrix



$$Y' = K_R \cdot R' + K_G \cdot G' + K_B \cdot B'$$

$$P_B = \frac{1}{2} \cdot \frac{B' - Y'}{1 - K_B}$$

$$P_R = \frac{1}{2} \cdot \frac{R' - Y'}{1 - K_R}$$

digital component video

$$K_R + K_G + K_B = 1$$

$$K_R = 0.299$$
$$K_G = 0.587$$
$$K_B = 0.114$$

Conclusions

- New topology of feedback
- Don’t limit your imagination (always investigate new solutions)
- Very high bandwidth (at low gain though)

Next lesson: **08 – OTA and ISO amplifiers**