Midterm

Lab 5

HW

Project

cascode op-amps

telescopic

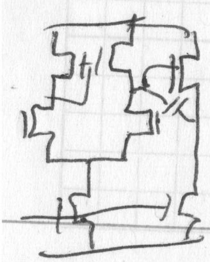
folded

2 stage : increase gain

decouple in/out CM/swing

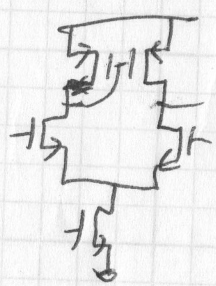
drive resistive loads (moderate)

problem : stability



Seen several op-amps now. All get used in practice

very common



limits : - input common mode } coupled

- output swing

- low gain

- high impedance loads only

good : simple!

easy biasing

single pole, PM ~ 90°

if we don't need resistive loads (i.e. just capacitive)

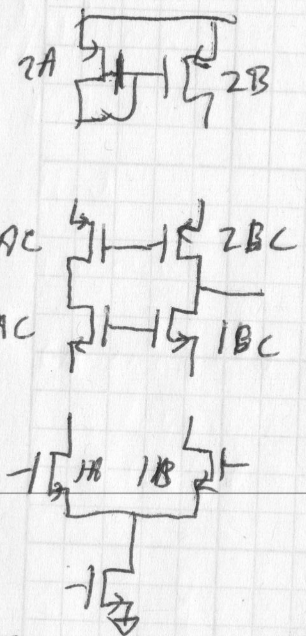
there are other topologies that are

- single stage } telescopic cascode } folded cascode

- high gain

- good-ish in/out CM/swing

EE 140/240A WI17 L7



Add $\begin{Bmatrix} 1BC \\ 2BC \end{Bmatrix}$ to increase output resistance, gain

(doesn't work w/ resistive load?)

Add $\begin{Bmatrix} 1AC \\ 2AC \end{Bmatrix}$ for symmetry and to improve/ease biasing

telescopic cascode

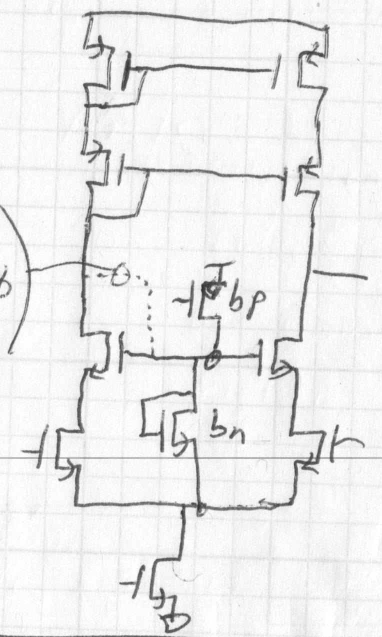
Simplest

easy, but restricts output swing

better: use bn, bp

size bn s.t.

$V_{gs_{bn}} \geq V_t + 2V_{ov1}$



9.8

fig 9.12

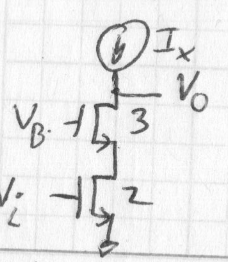
good: high gain

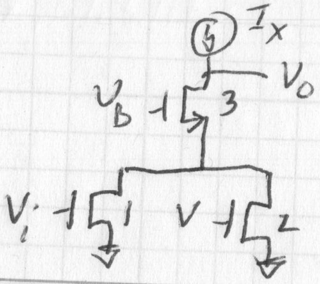
single pole $\Rightarrow$ stable

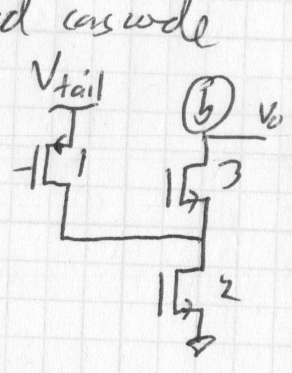
not so good: in/out cm/swing

So... very popular solution: folded cascode

"folding"



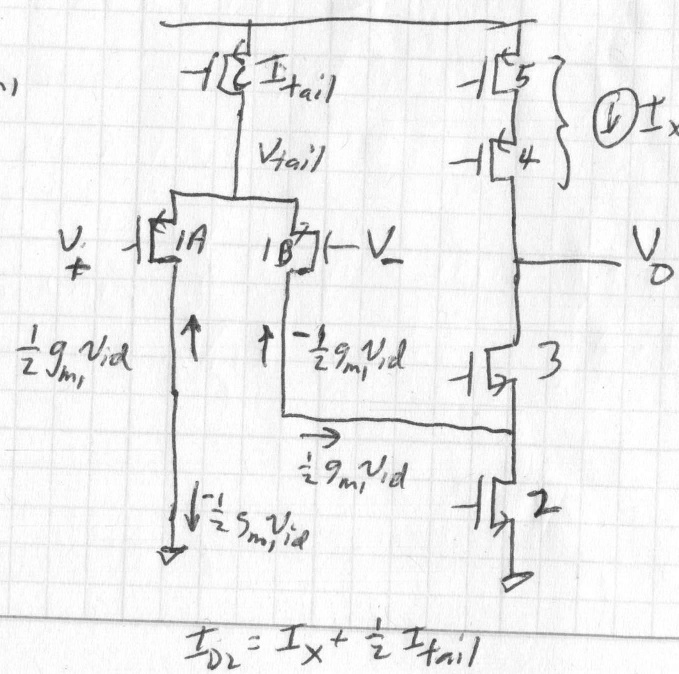




$-g_{m2}(g_{m3} r_{o3} r_{o2}) \quad -g_{m1}(g_{m3} r_{o3})(r_{o1} \| r_{o2}) \Longrightarrow$ same!

$G_m = -\frac{1}{2} g_{m1}$

$R_o = ?$



$I_{D2} = I_x + \frac{1}{2} I_{tail}$

$R_o = R_{UP} \| R_{DN}$ $\quad R_{UP} \simeq g_{m4} r_{o4} r_{o5}$

$R_{DN} = g_{m3} r_{o3} (r_{o2} \| r_{o1B})$

typically

$I_{D3,4,5} \simeq I_{D1A,D1B}$

if so $I_{D2} = I_{D3} + I_{D1B} = 2 I_{D1B}$

$r_{o2} = \frac{1}{\lambda_n 2 I_{D1B}}$ $\quad r_{o1B} = \frac{1}{\lambda_p I_{D1B}}$

if $\lambda_n \simeq \lambda_p$ then $r_{o2} \simeq \frac{1}{2} r_{o1B}$

$r_{o2} \| r_{o1B} = \frac{1}{3} r_{o1B} = \frac{1}{3} r_{o3,4,5}$

$R_{DN} = g_{m3} r_{o3} \left(\frac{1}{3} r_{o3,4,5}\right)$

$R_{UP} \| R_{DN} \simeq \frac{1}{4} g_m r_o^2$

$A_v = -G_m R_o = +\frac{1}{8} (g_m r_o)^2$

output swing

$V_{o,min} = V_{G3} - V_{tn} \geq V_{OV2} + V_{OV3}$

↑ depends on how you bias V_{G3}

$V_{o,max} = V_{G4} + |V_{tp}| \leq V_{DD} - |V_{OV4}| - |V_{OV5}|$

↑

Input common mode

$V_{icm,max} = V_{DD} - |V_{OV6}| - |V_{tp}| - |V_{OV1}|$

$V_{icm,min} = V_{S3} - |V_{tp}|$

$V_{S3} = V_{G3} - V_{tn} - V_{OV3} \geq V_{OV2}$

lowest possible

$V_{icm,min} = V_{OV2} - |V_{tp}| < 0$

input common mode below ground!