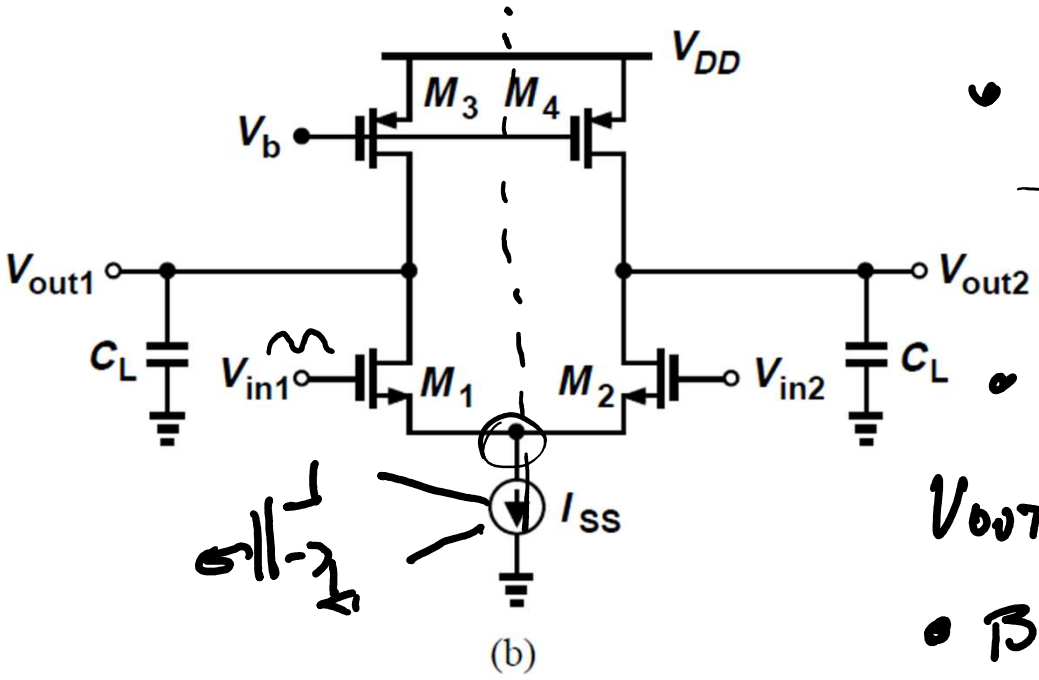
Lecture #15, Feb 11th, 2022

- We will bounce between chapters 8 (Feedback) and 9 (Op Amp design).
- CAD 4 now out.
- Quiz on Monday
- Project 1 Due Next week
- Project 2 coming soon.
- Today:
  - Continue with Op Amp Design

- SIMPLE DIFF PAIR W/ ACTIVE.
- TELESCOPIC OP AMP.
- FOLDED CASCODE
- OR 2-STAGE OP AMP
  - REGULATED CASCODES.

Output Swing (Headroom), BW and Gain



(b)

- $A_V = -g_{m1} \cdot (r_{O1} \,//\, r_{O3})$

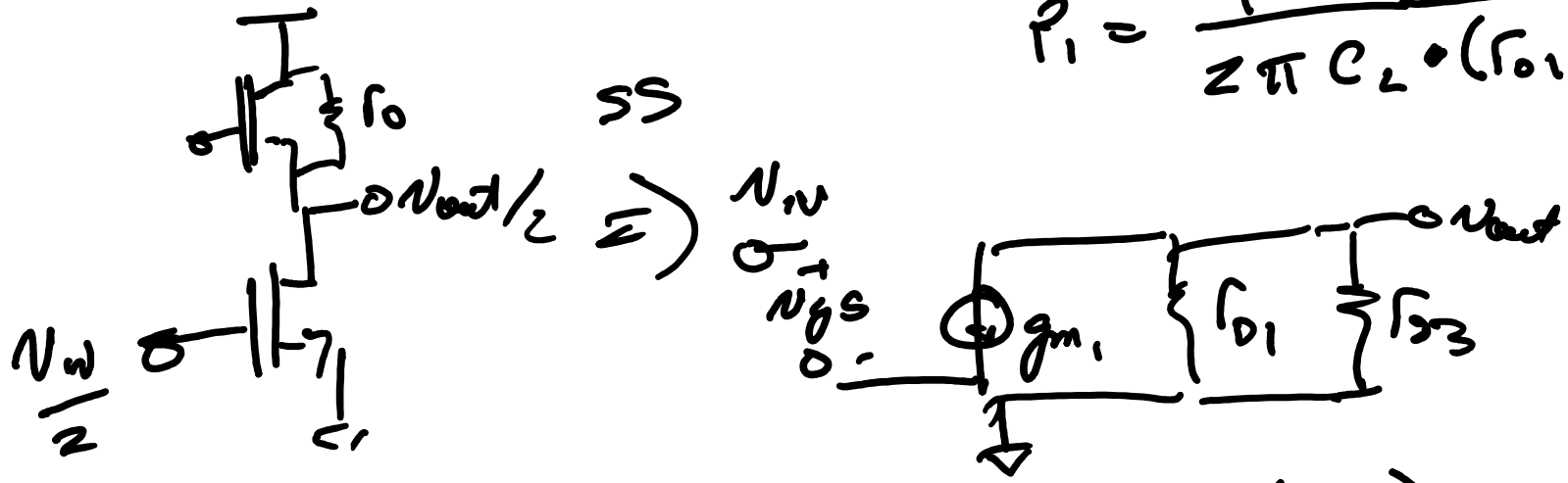
DECENT GAIN $\rightarrow$ $A_V \angle 100$

- OUTPUT SWING - E.G. HEADROOM

$V_{OUT,MAX} = V_{DD} - 3 \cdot V_{DSAT}$

- BW : ONE DOMINATE POLE

$$P_1 = \frac{1}{2\pi C_L \cdot (r_{O1} \,//\, r_{O3})}$$

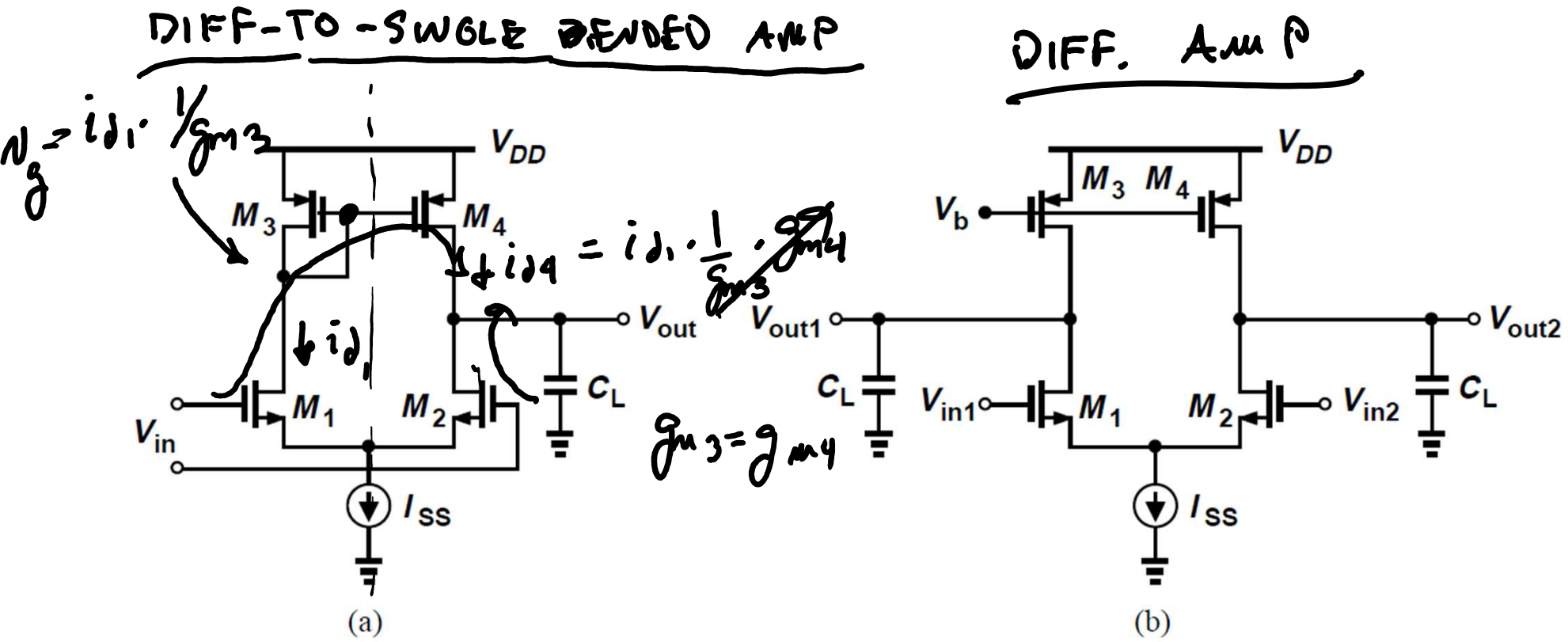


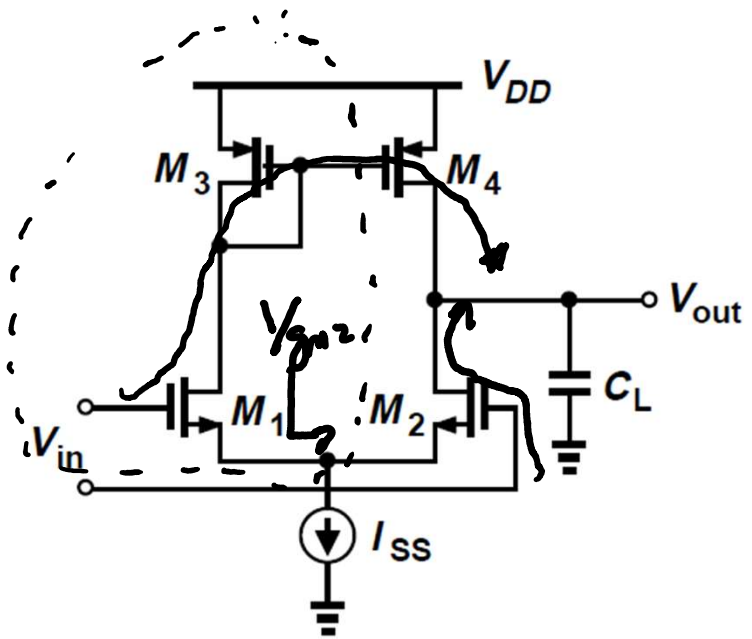
$A_V = -g_{m1} (r_{O1} \,//\, r_{O3})$

VERY STABLE

One-Stage Op Amps

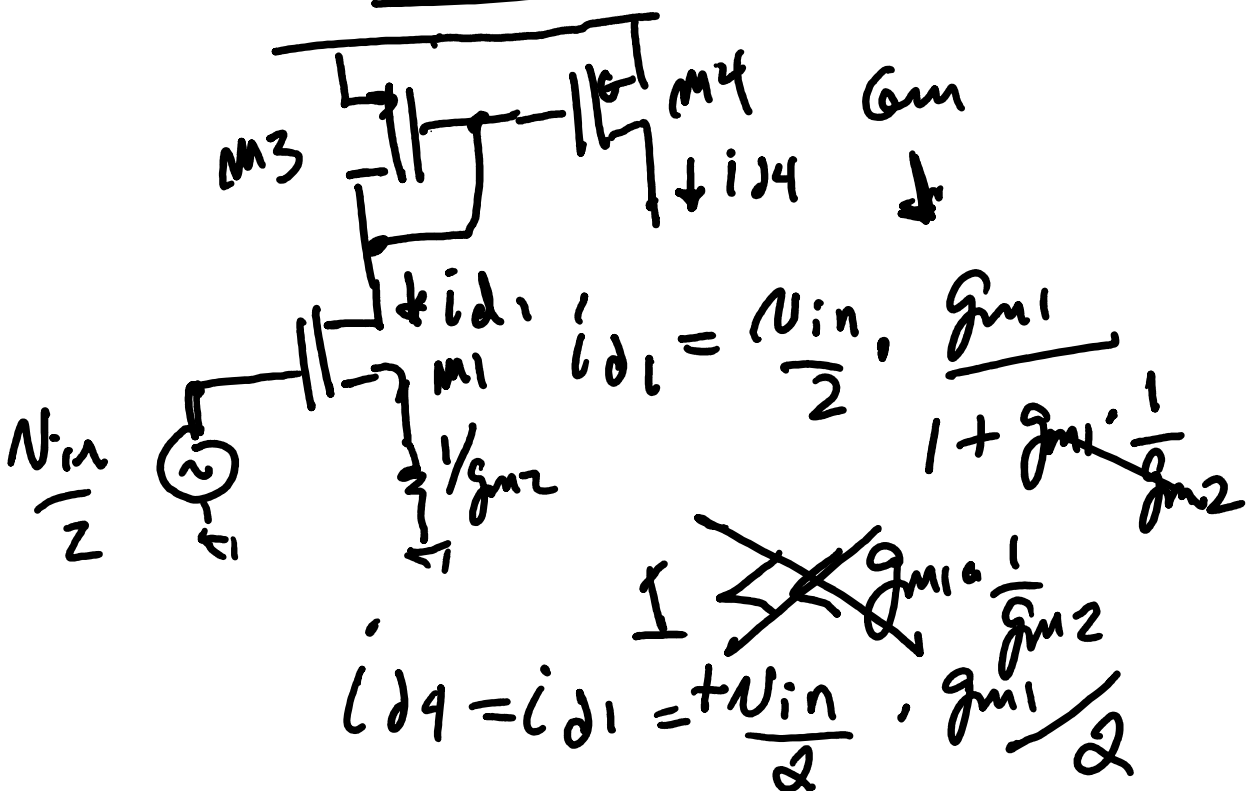
- Low-frequency gain:
- Bandwidth: usually proportional to 1/(CL*Rout)
- Output Swing (single-side): VDD-3Overdrive
- Mirror pole in single-ended circuit
- Power and noise: good, with four devices -> input noise



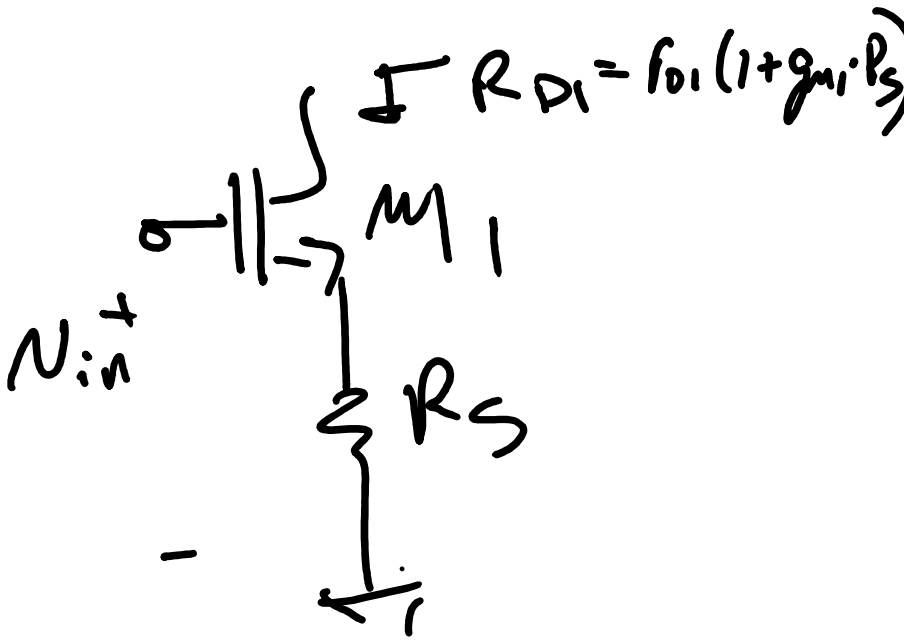


(a)

LEFT GAIN



CS w/ R_{DEGEN}

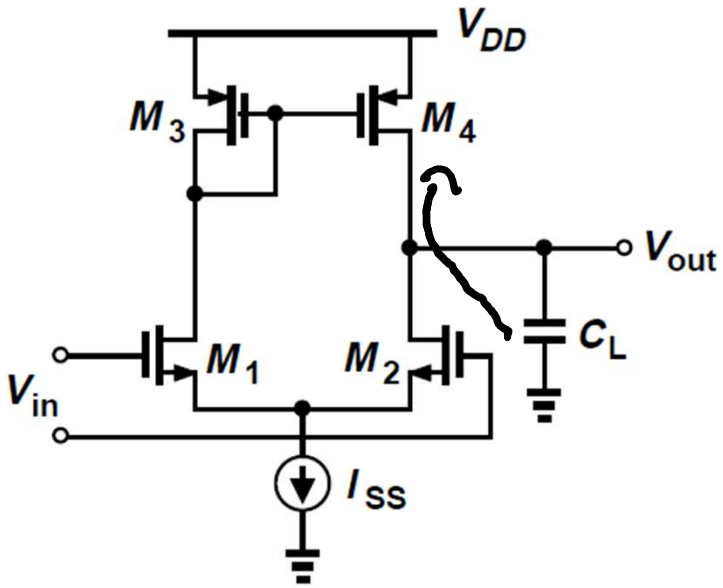


$G_m \cong 1/R_S$ if

$G_m = \frac{g_{m1}}{1 + g_{m1} \cdot R_S}$

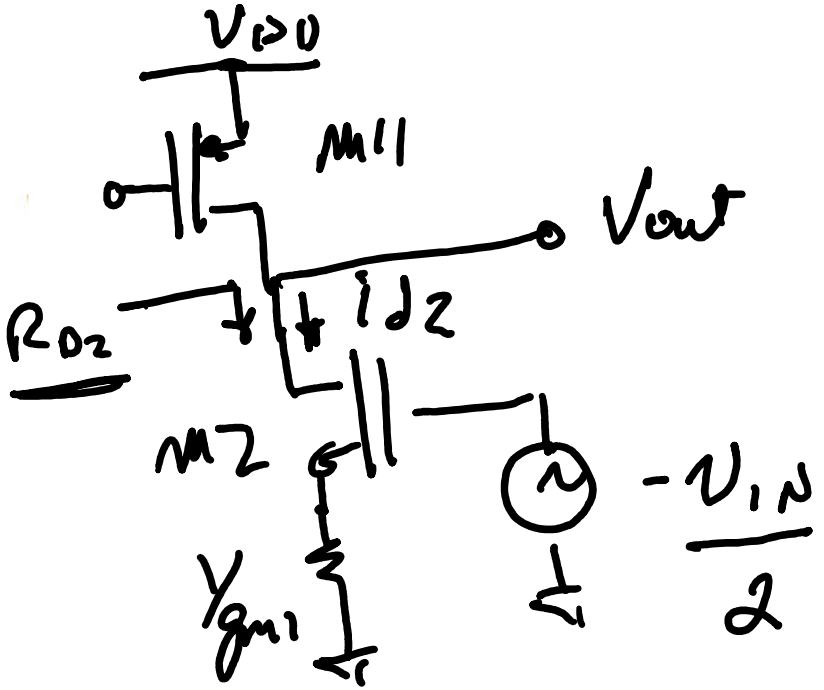
$1 \ll g_{m1} R_S \Rightarrow$

$G_m = 1/R_S$



(a)

RIGHT SIDE



$$i_{d2} = -\left(-\frac{V_{in}}{2}\right)\cdot\frac{g_{m2}}{1+g_{m2}\cdot\frac{1}{g_{m1}}}$$

$$= +\frac{V_{in}}{2}\cdot\frac{g_{m2}}{2}$$

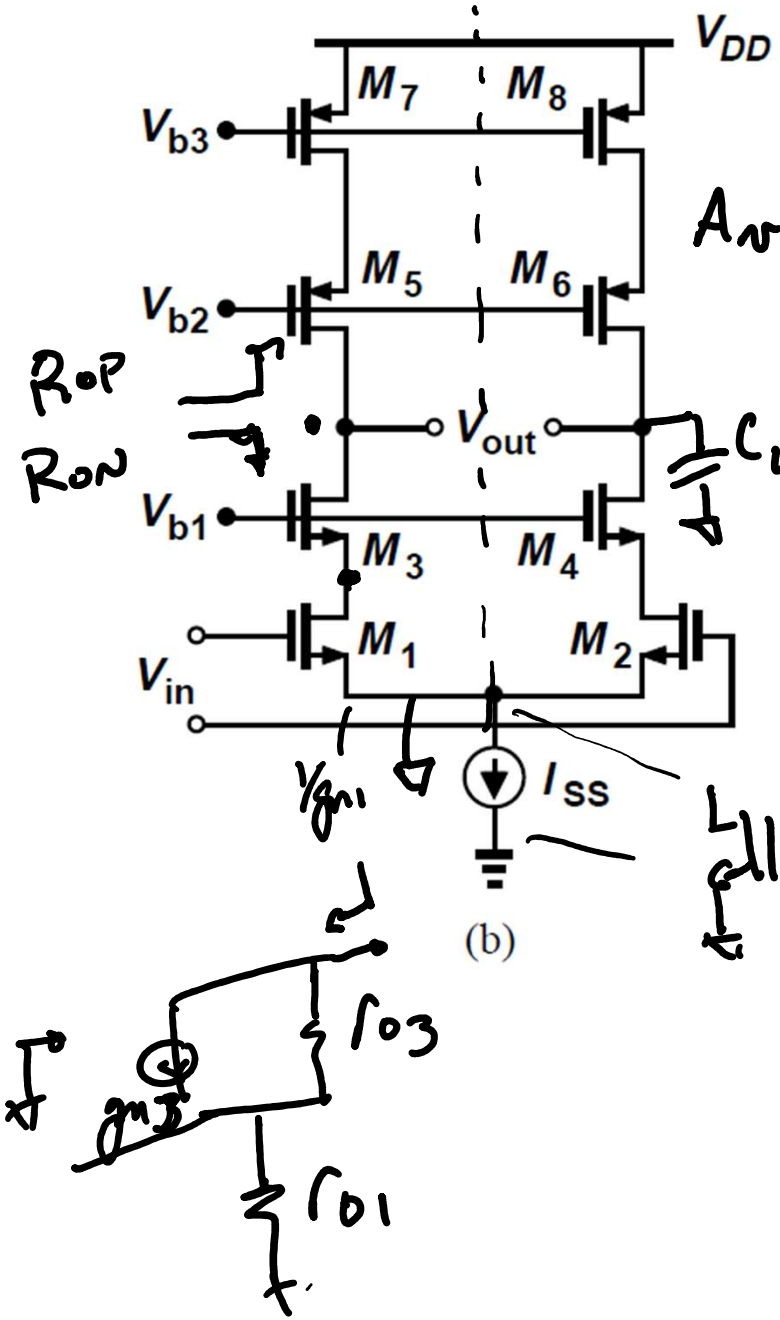
$$R_{D2} = r_{o2}\left(1+g_{m2}\cdot\frac{1}{g_{m1}}\right)$$

$$= r_{o2}\cdot 2$$

$$V_{out} = (i_{d4}+i_{d2})\cdot(r_{o4}\,//\,2r_{o2})\,v_{in} = \frac{g_{m1}}{2}\cdot\left(\frac{g_{m1}}{2}+\frac{g_{m2}}{2}\right)\cdot(r_{o4}\,//\,2\cdot r_{o2})$$

$$A_0 = g_m\cdot(r_{o4}\,//\,2\cdot r_{o2})$$

Telescopic Cascode Op Amps



- VOLTAGE GAIN

$$A_V = -g_{m1}\cdot\left(g_{m3}\cdot r_{o3}\cdot r_{o1} \;//\; g_{m5}\cdot r_{o5}\cdot r_{o7}\right)$$

INTRINSIC (10-100)

- OUTPUT SWING

$V_{out,max} = V_{DD} - 5\,V_{DSAT}$; POOR OUTPUT SWING

$(V_{GS} - V_{TH})$

- BW

$$P = \frac{1}{2\pi\,(R_{ON} // R_{OP})\cdot C_L}$$

DOMINATE POLE

STABLE