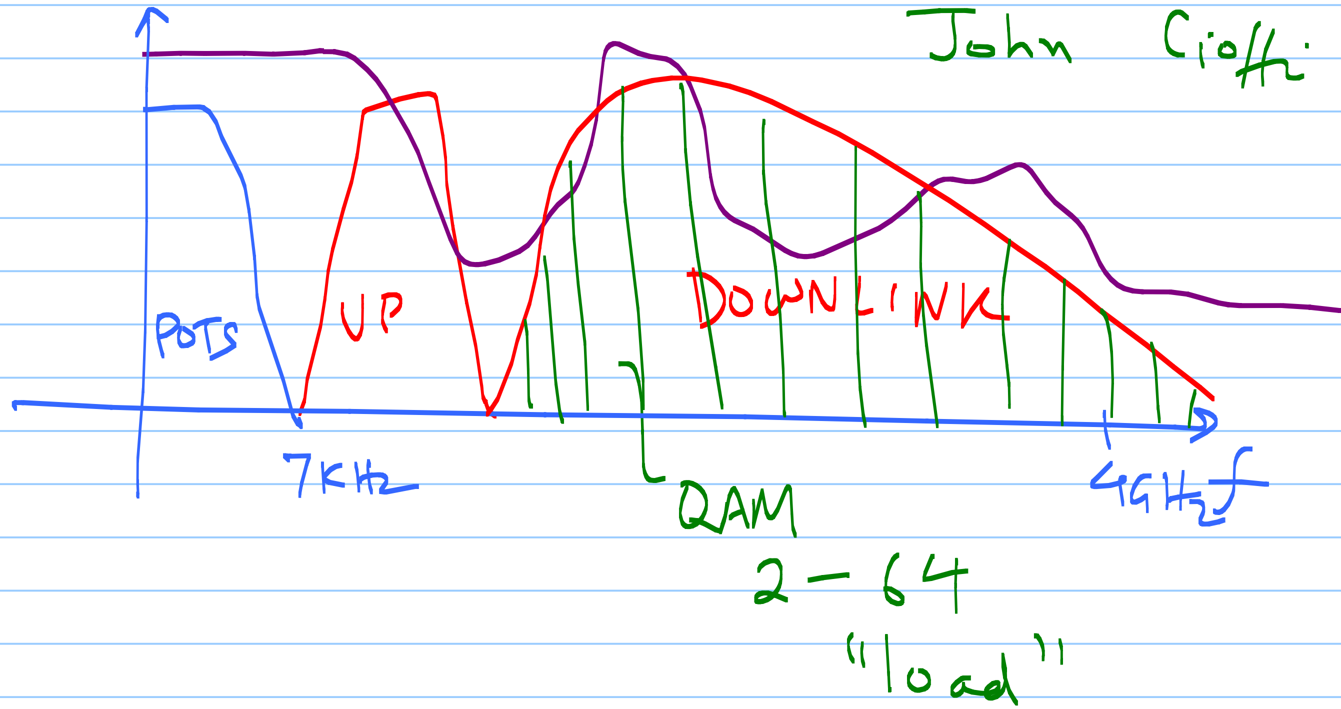
ECE 5411 — Lecture 9

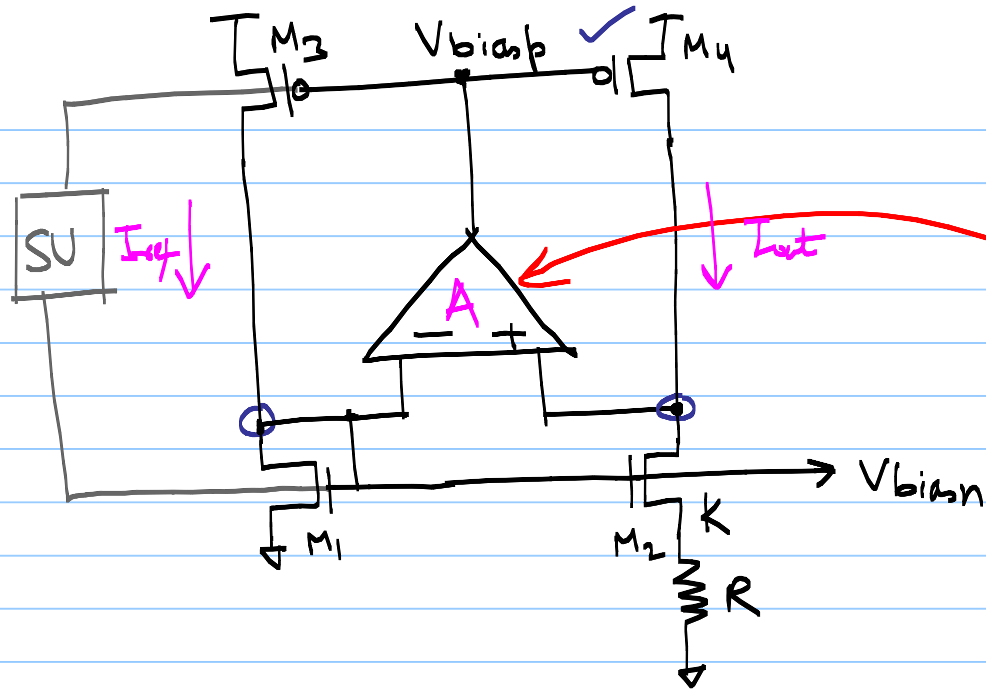
Note Title 2/16/2011

ASIDE

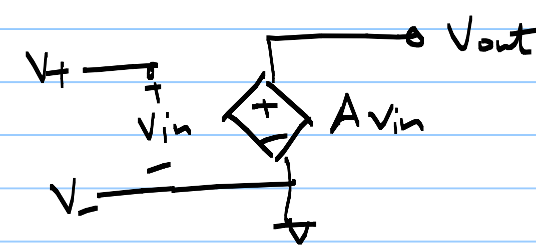
ADSL

John Cioffi

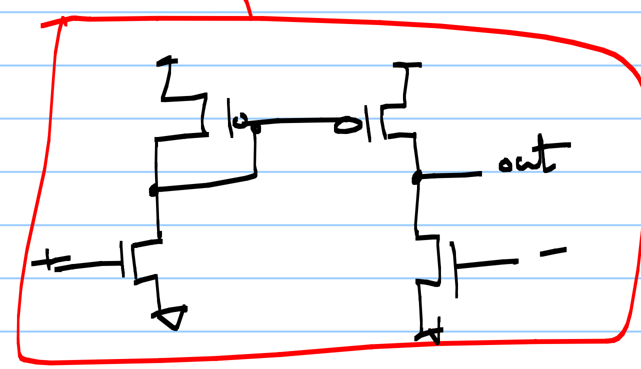


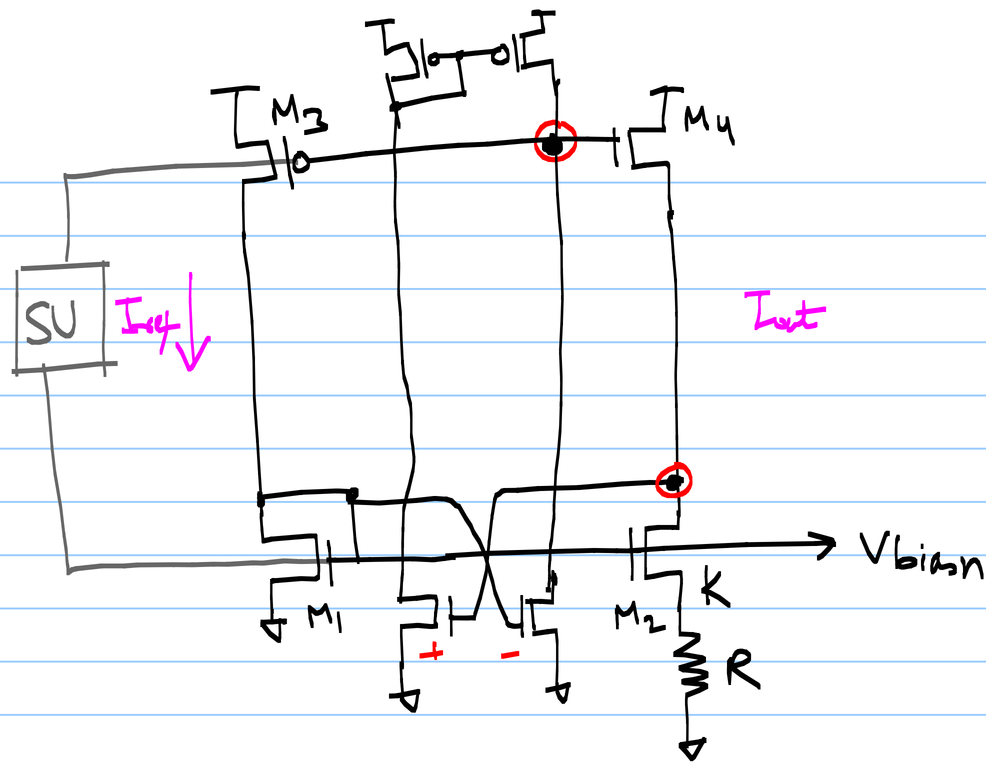


VCVS



"Error Amplifier"





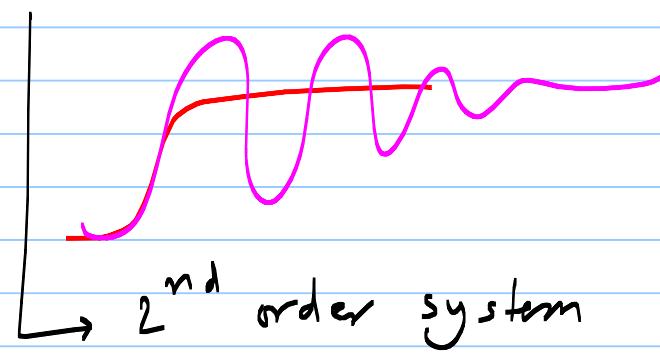
Modify → get rid of one of the hi-Z node

r_o $\quad$ $1/g_m$

Hi-Z $\quad$ Lo-Z

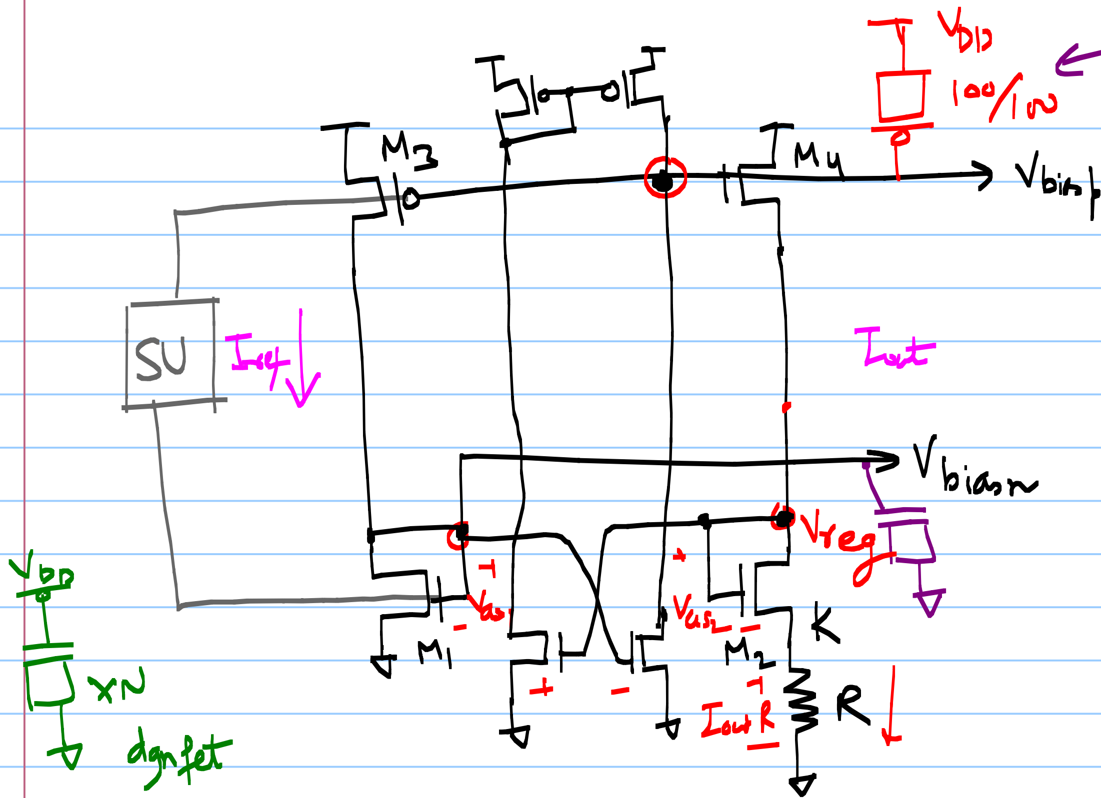
2-hi-Z (high impedance)

"COMPENSATION"

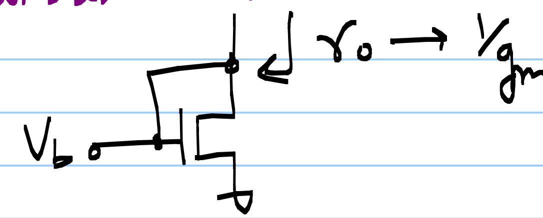


2nd order system

2- dominant poles



← compensation Caps



$$\boxed{V_{GS_1} = V_{GS_2} + I_{out}R}$$

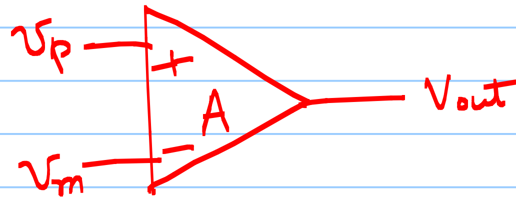
for Large A

↳ I_{out} is independent of V_{DD}.

1st order system

↳ loop-gain is reduced due to diode-connected MOSFET.

Digressin



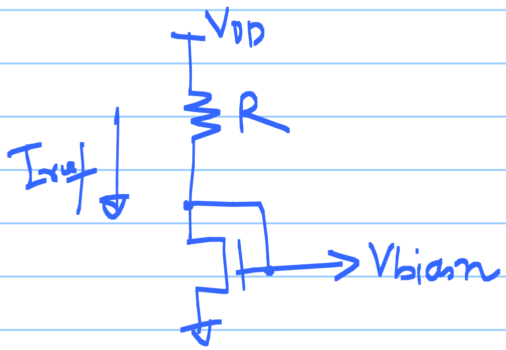
$\boxed{\text{Fig. 20.23 \& 20.24}}$

$$v_{out} = A(v_p - v_m)$$

finite value $\qquad \infty \times (\ 0\ )$

$$A \to \infty \Rightarrow v_p \triangleq v_m$$

Temperature Behavior of Current references



$$I_{ref} = \frac{V_{DD} - V_{GS}}{R}$$

$$\frac{\partial I_{ref}}{\partial T} = -\frac{(V_{DD} - V_{GS})}{R^2} \cdot \frac{\partial R}{\partial T} - \frac{1}{R} \cdot \frac{\partial V_{GS}}{\partial T}$$

$$= -\frac{I_{ref}}{R} \cdot \frac{\partial R}{\partial T} - \frac{1}{R} \cdot \frac{\partial V_{GS}}{\partial T}$$

$$TC_{I_{ref}} = \frac{\left(\frac{\partial I_{ref}}{\partial T}\right)}{I_{ref}} = \underbrace{-\frac{1}{R} \cdot \frac{\partial R}{\partial T}}_{TC_R} - \underbrace{\frac{1}{(V_{DD} - V_{GS})}}_{\text{change with operating point}} \cdot \boxed{\frac{\partial V_{GS}}{\partial T}}$$

BMR.

$$I_{ref} = \frac{2}{R^2 \, K\rho_n \frac{W}{L}} \left(1 - \frac{1}{\sqrt{K}}\right)^2 \rightarrow \alpha$$

$$\frac{\partial I_{ref}}{\partial T} = \frac{-4\alpha}{R^3 K\rho_n \frac{W_1}{L_1}} \cdot \frac{\partial R}{\partial T} - \frac{2\alpha}{R^2 K\rho_n^2 \frac{W_1}{L_1}} \frac{\partial K\rho_n}{\partial T}$$

$$TC_{I_{ref}} = \frac{\left(\frac{\partial I_{ref}}{\partial T}\right)}{I_{ref}} = -2\underbrace{\left(\frac{1}{R} \cdot \frac{\partial R}{\partial T}\right)} - \underbrace{\frac{1}{K\rho_n} \cdot \frac{\partial K\rho_n}{\partial T}}$$

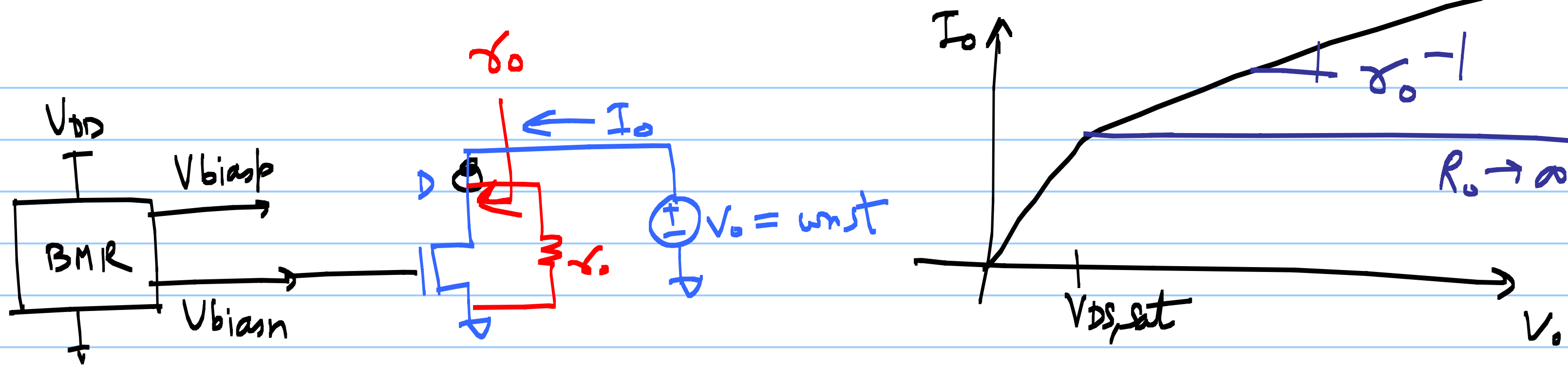
1000 ppm/°C

$$= \underbrace{-2 \, \underbrace{TC_R}_{+ve}}_{-ve} - \underbrace{\underbrace{TC_{K\rho_n}}_{-ve}}_{+ve}$$

$$\frac{1.5}{T} = \frac{1.5}{300}$$

$$= -0.004 + \frac{1.5}{300} = 1000 \text{ ppm}/°C$$

Band gap References
(BGR)

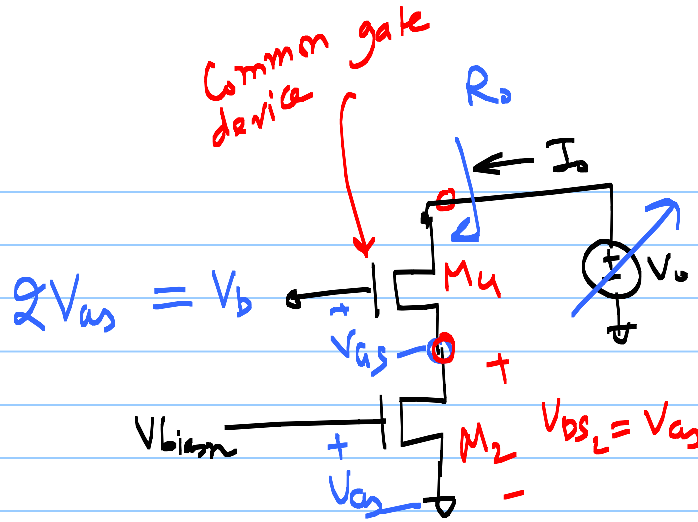


$V_o > V_{DS,sat}$

* We want the output resistance (R_o) of the current mirror to be very high
↳ so that it behaves like an ideal current source.

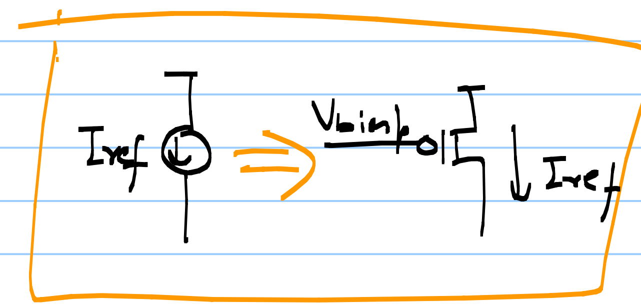
* In other words, if we can hold V_{DS} of the current mirror, then I_o will not vary much.

"CACODE CURRENT MIRROR"

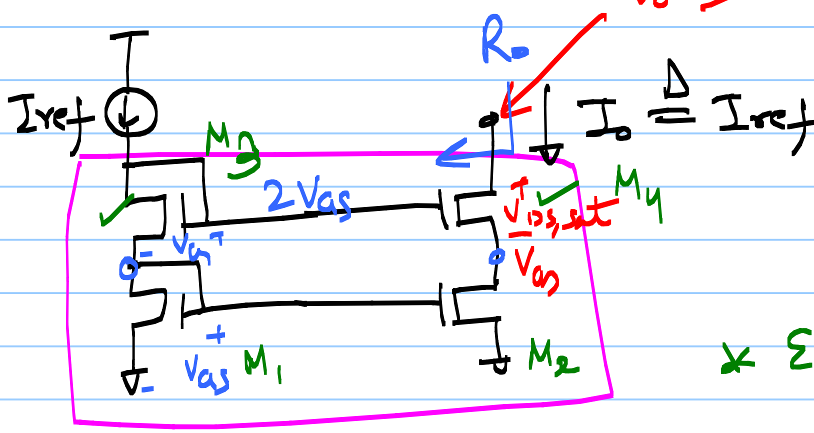


I_o is fixed by the bottom devices only

$V_b = 2\,V_{GS}$



$V_o \geq V_{GS} + V_{DS,sat}$

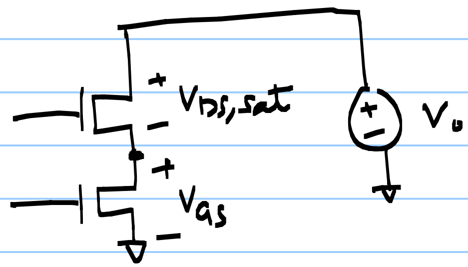


cost : Lower voltage headroom (Extra V_{GS})

" swing

* Even if M_3 & M_4 have body-effect

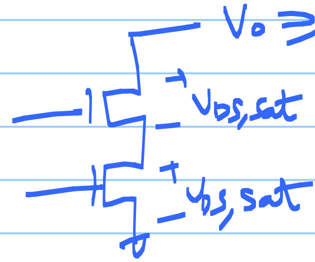
→ the drains of M_1 & M_2 are held together



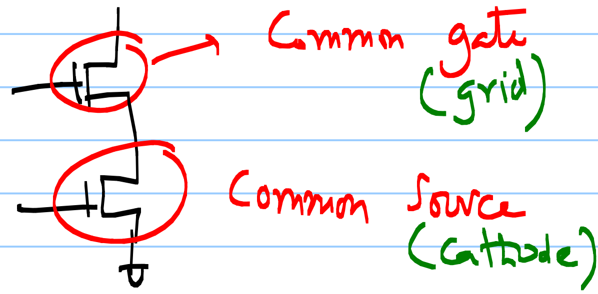
$$V_o \geq V_{GS} + V_{DS,sat}$$

$$\simeq V_{THN} + \underbrace{2V_{DS,sat}}$$

$V_o \geq 2V_{DS,sat}$



* we are wasting one "V_{THN}"!



CASCODE = Cascade of Common Cathode & Common Grid amplifier.