

## Recitation 24: BiCMOS Cascode Amplifier

Yesterday, we talked about Multistage amplifiers. The simplest way to have multi-stage amplifiers is to directly connect the output of the previous stage to the next stage, as we talked about yesterday. We call this way “cascade”.

Today we will talk about another topology - “cascode” (Before doing that, we can have a simple exercise) What is the following amplifier and what is its function?

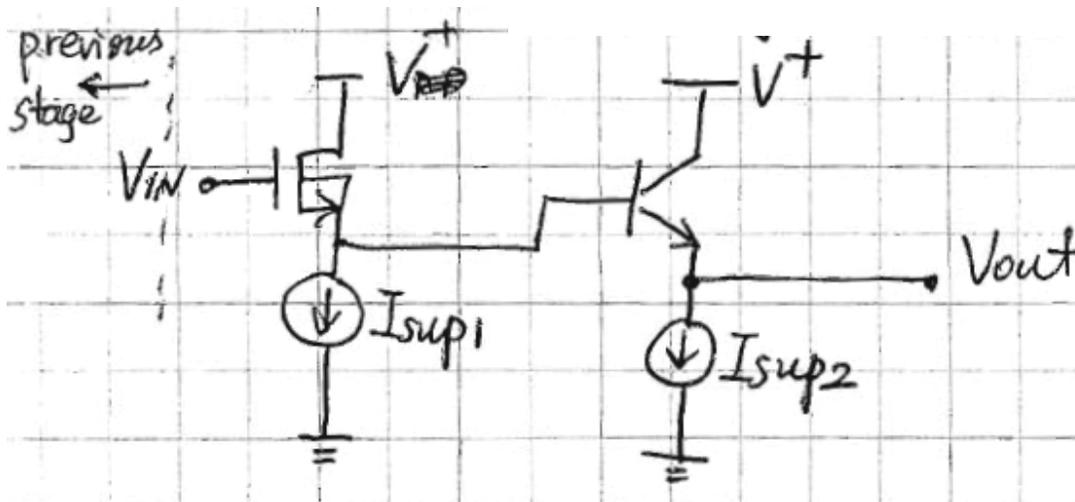


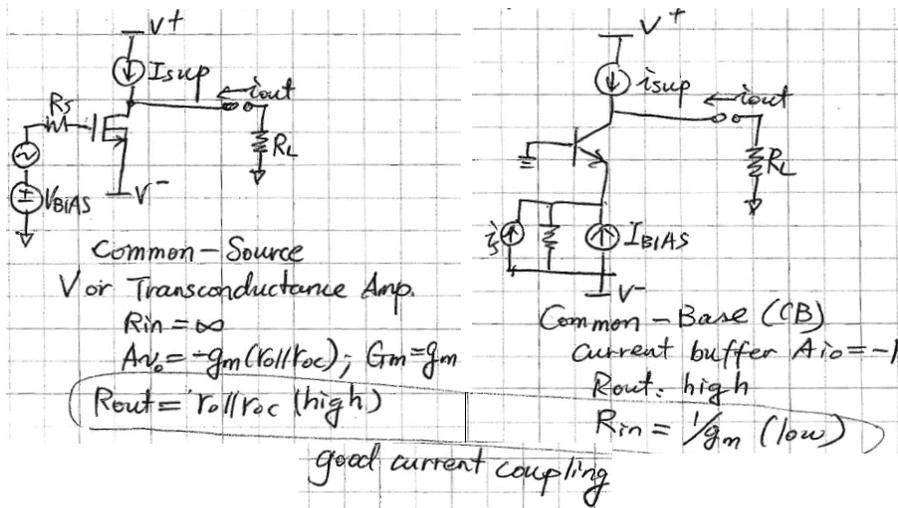
Figure 1: This is a CD-CC Voltage Buffer. Since  $R_{in}$  of CD is  $\infty$ , this can couple very well with the voltage signal of the previous stage, even there is a high  $R_{out}$  at the previous stage

And CC  $R_{out} = \frac{1}{g_m} + \frac{R_s}{\beta_o} \cdot g_m$  (BJT) typically  $> g_m$  (MOS) having CC could reduce final  $R_{out}$ .

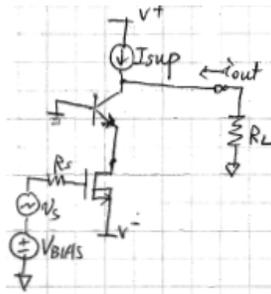
### BiCMOS Cascode Amplifier

We would like to put these two together.

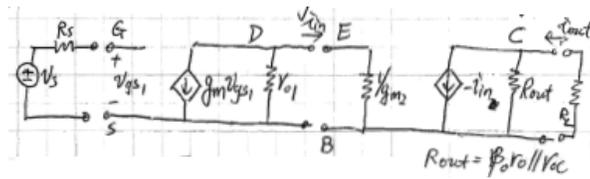
(You will see advantages later: MOS has large  $R_{in}$  and BJT has good frequency response)



But instead "cascading", we do the following:



Let us look at the small signal model (low frequency)



$$R_{out} = \gamma_o [1 + g_m(\gamma_\pi || R_s)] || \gamma_{oc}$$

$$R_s = \gamma_{o1}$$

$$\gamma_{o1} \quad (\text{MOS}) \text{ typical } 100 \text{ k}\Omega$$

$$\gamma_\pi \sim 10 \text{ k}\Omega, \gamma_\pi || R_s = \gamma_\pi$$

$$R_{out} = \gamma_o [1 + \underbrace{g_m \gamma_\pi}_{\beta_o}] || \gamma_{oc} = \beta_o \gamma_o || \gamma_{oc}$$

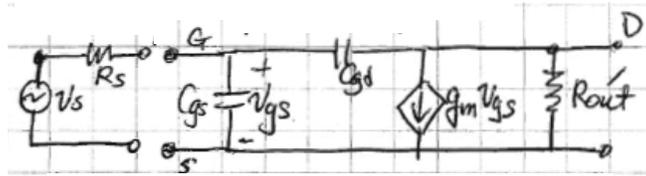
$$\text{Transconductance Gain } G_m = \frac{i_{out}}{v_s}$$

$$= \frac{-i_{in}}{v_s} = \frac{\overbrace{\frac{\gamma_{o1}}{\gamma_{o1} + \frac{1}{g_{m2}}} \cdot (g_m v_{gs1})}^{\sim 1}}{v_s} = g_m$$

It is the same as CS amplifier itself! Why would we want to add the CB stage?

## Frequency Response

1. Frequency response of CS

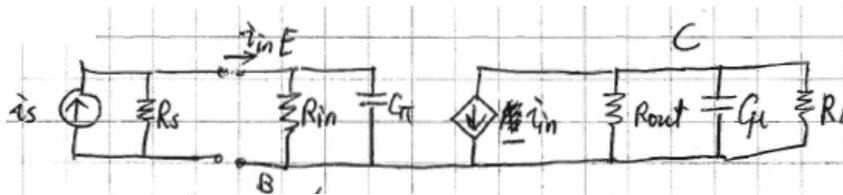


$$R'_{out} = \gamma_o || \gamma_{oc} || R_L$$

$$\omega_{3dB} = \frac{1}{R_s C_{gs} + R_s C_{gd} (1 + g_m R'_{out}) + R'_{out} \cdot C_{gd}}$$

Miller effect:  $C_{gd}$  multiplied (amplified) by gain  $g_m R'_{out}$

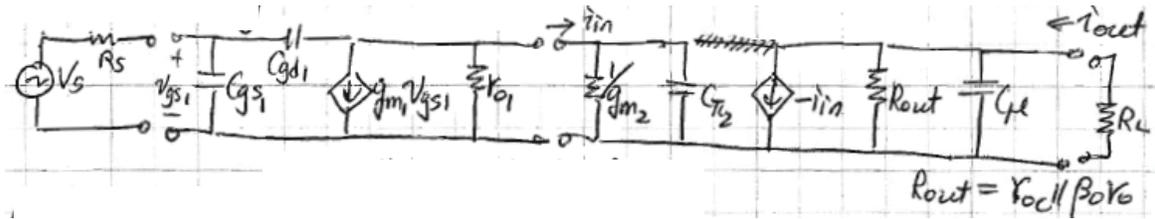
2. Frequency response of CB



$$R_{in} = \frac{1}{g_m}, \quad R_{out} = \gamma_{oc} \parallel \gamma_o \beta_o$$

$$w_{3dB} = \frac{1}{(R_s \parallel R_{in})C_\pi + (R_{out} \parallel R_L) \cdot C_\mu} \simeq \frac{1}{\frac{C_\pi}{g_m} + C_\mu \cdot R_L}$$

3. Now combining the two together



Apply OCT technique (+ Miller Approximation) for frequency response:

(a)  $C_{gs1}$  :  $R_{THC_{gs1}} = R_s$

(b)  $C_{gd1}$ : voltage gain across  $C_{gd1}$  is

$$\frac{V_{\pi_2}}{V_{gs1}} = -\frac{-g_m V_{gs1} \left( \gamma_o \parallel \frac{1}{g_{m2}} \right)}{V_{gs1}} \simeq -\frac{g_{m1}}{g_{m2}}$$

$$\therefore C_M = C_{gd1} (1 - A_{vC_{gd1}}) C_{gd1}$$

$$R_{THC_M} = R_s$$

(c)  $C_{\pi_2}$  :  $\gamma_{o1} \parallel \frac{1}{g_{m2}} \simeq \frac{1}{g_{m2}}$

(d)  $C_\mu$  :  $R_{out} \parallel R_L \simeq R_L$

$$\therefore w_{3dB} = \frac{1}{R_s C_{gs1} + R_s C_{gd1} \left( 1 + \underbrace{\frac{g_{m1}}{g_{m2}}}_{\leq 1} \right) + \frac{C_\pi}{g_{m2}} + C_\mu R_L}$$

For BiCMOS cascode, Miller effect is drastically reduced compared to CS case.

$C_{gd}$  is multiplied by  $\left( 1 + \frac{g_{m1}}{g_{m2}} \right)$ .

$$\text{BJT } (g_{m2}) \geq g_{m1} \text{ (MOS)}$$

$$1 + \frac{g_{m1}}{g_{m2}} \leq 2$$

Therefore, BiCMOS cascode amplifier has overall voltage gain of C-S, but with frequency response comparable to CB Amplifier.

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6.012 Microelectronic Devices and Circuits  
Spring 2009

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