INF3410/4411, Fall 2018

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Excerpt of Sedra/Smith Chapter 7: Integrated CMOS Amplifier Basics

Content

Bias Current Steering (book 7.2)

CS, CG, and cascode configuration (book 7.3-7.5)

Improved Current Mirrors/Sources (book 7.6)

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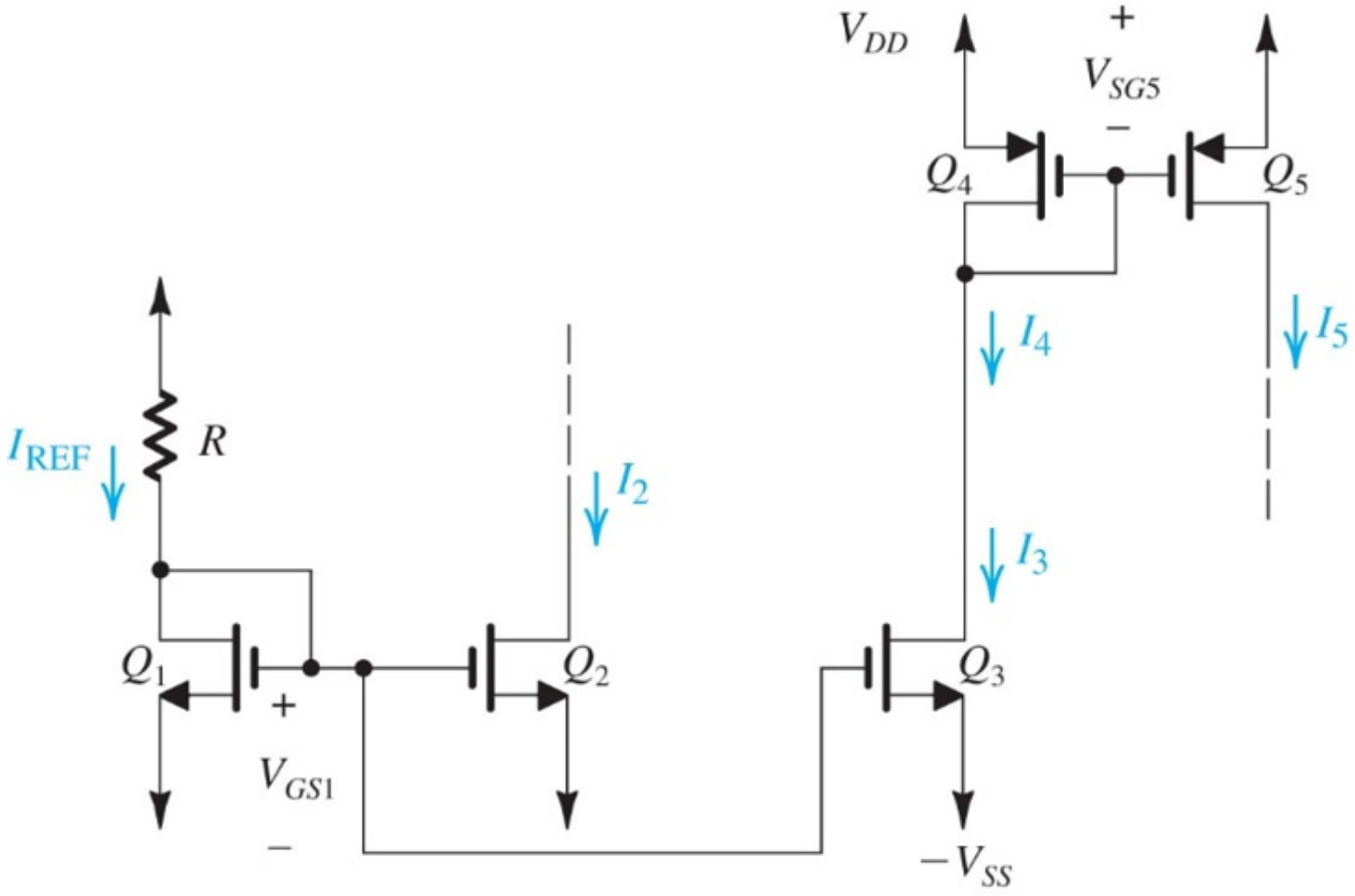
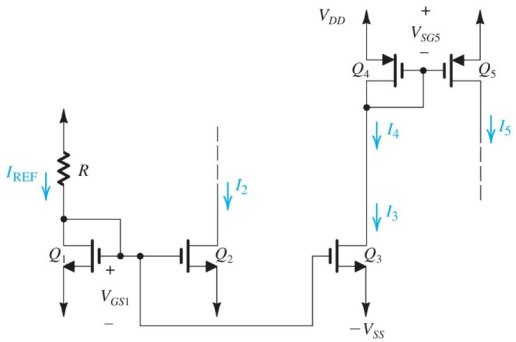
CMOS Current Steering



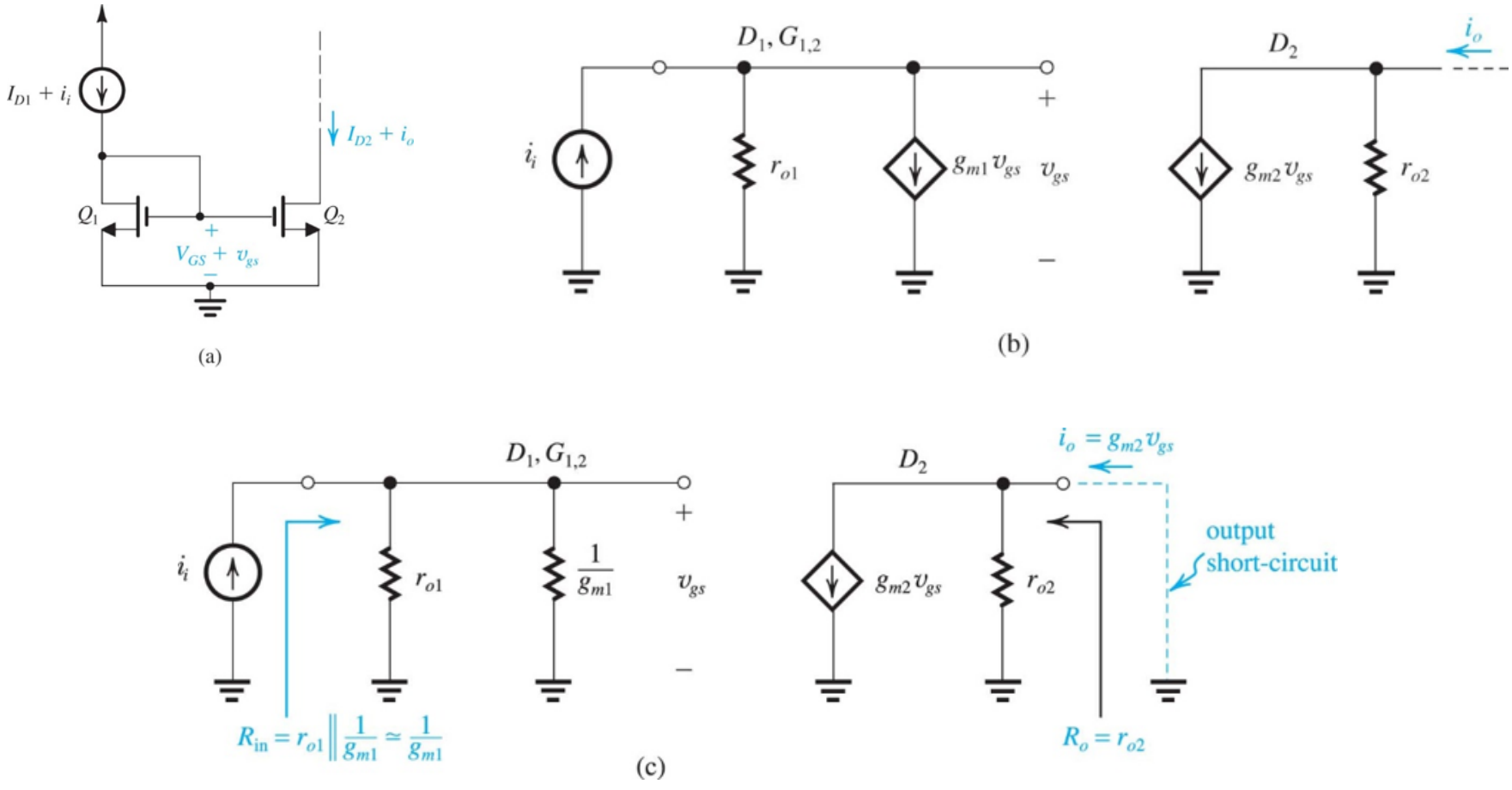
Computing R_{ref} CMOS Current Steering

(live on whitebord)



Wrong: using the small signal input resistance $\frac{1}{g_m}$ for a desired I_D
Correct: Use large signal model!!!

Dynamic Input Currents, Current Amplifier



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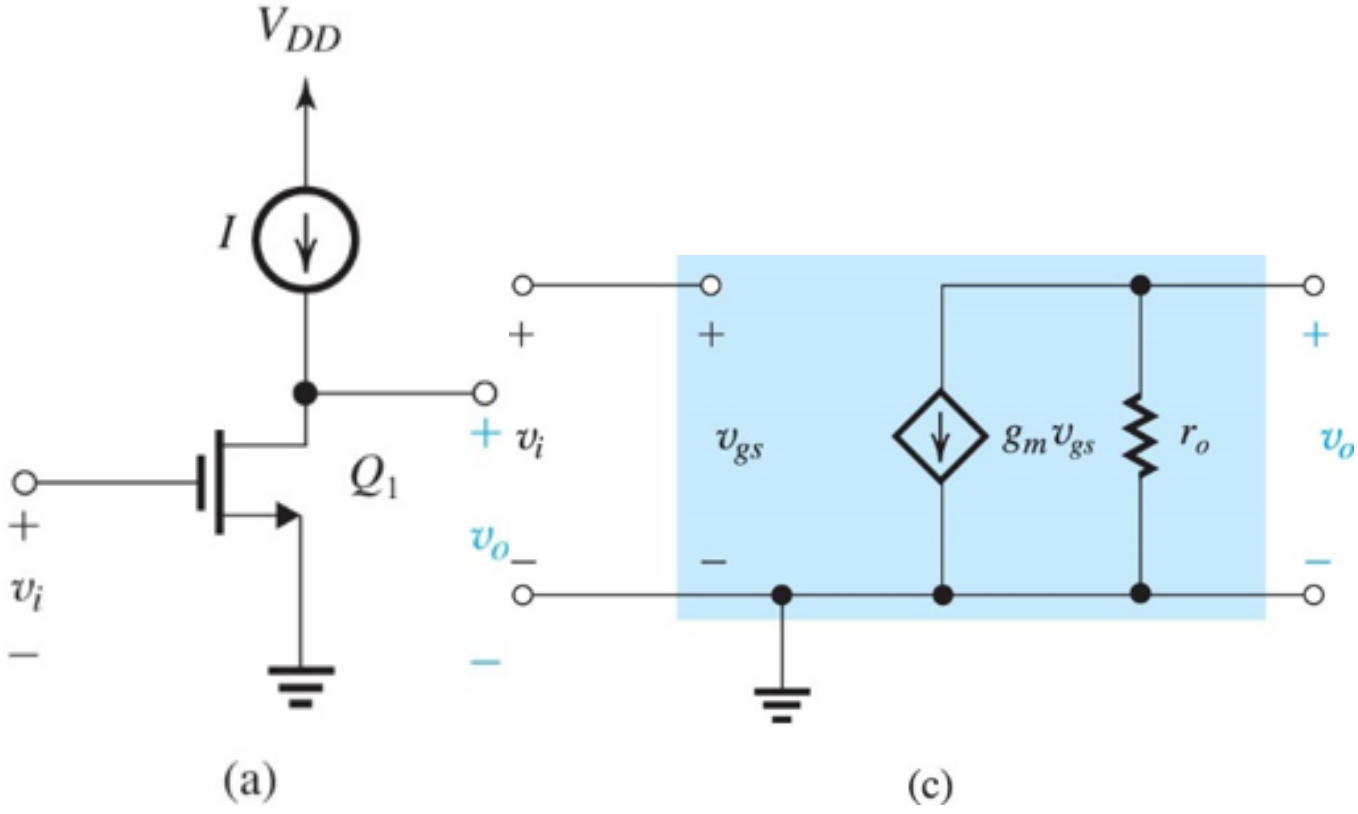
Bias Current Steering (book 7.2)

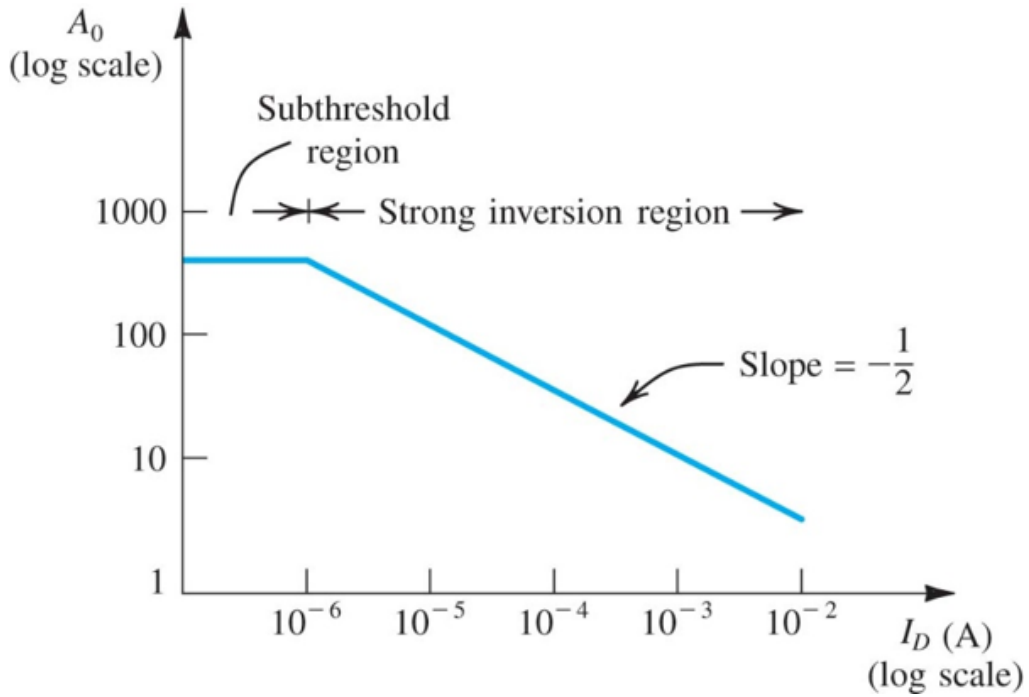
CS, CG, and cascode configuration (book 7.3-7.5)

Improved Current Mirrors/Sources (book 7.6)

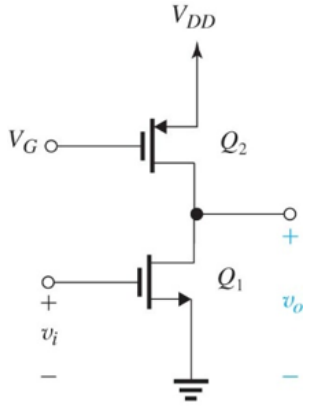
Intrinsic Gain from Small Signal



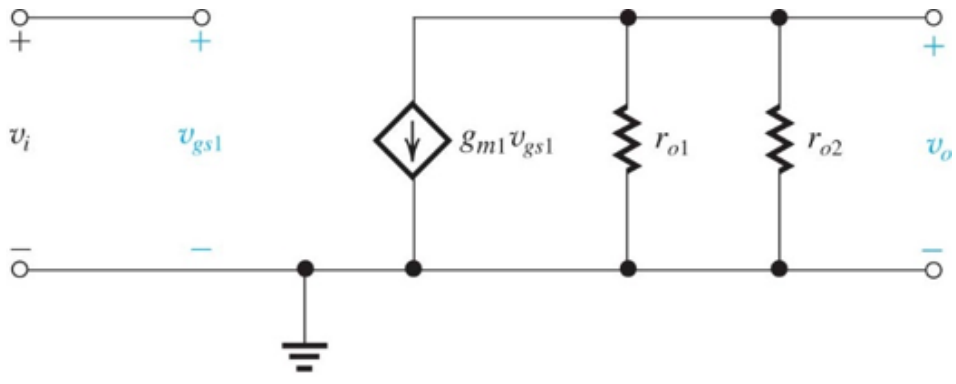
Intrinsic Gain vs Bias Current



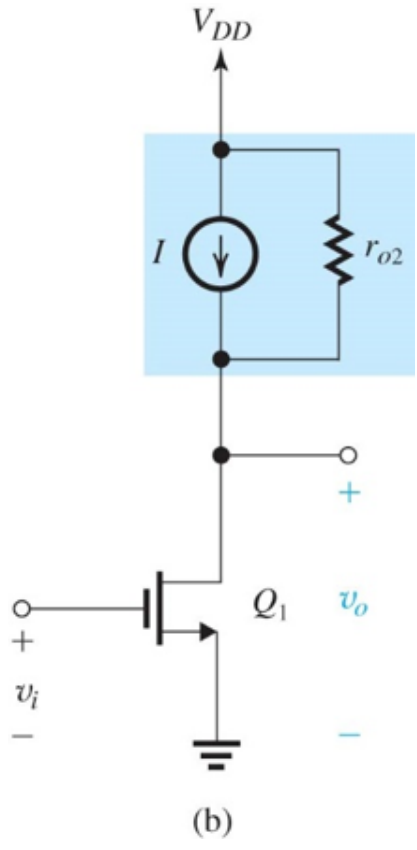
CS Amplifier with Current-Source Load



(a)

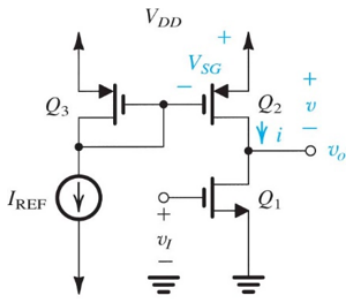


(c)

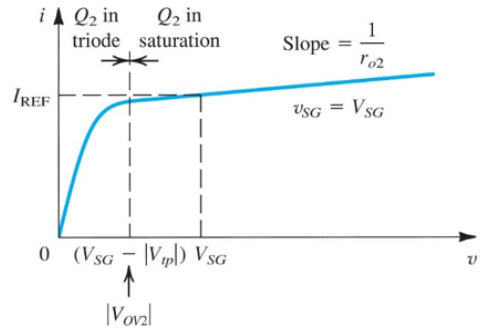


(b)

CS Amplifier Analysis



(a)



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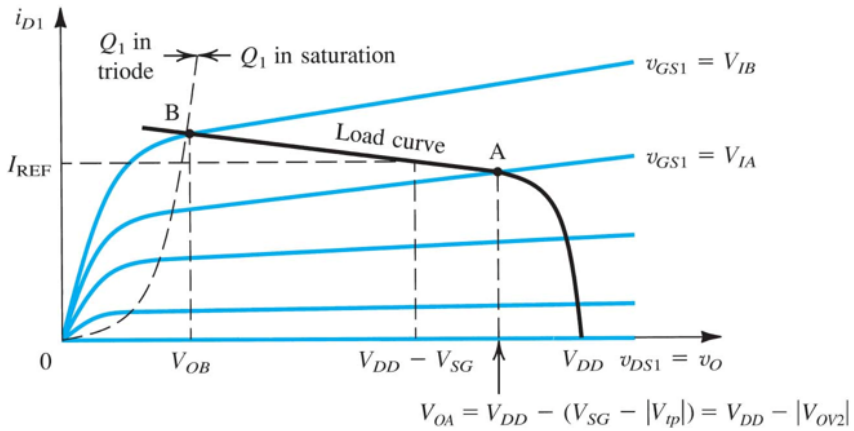

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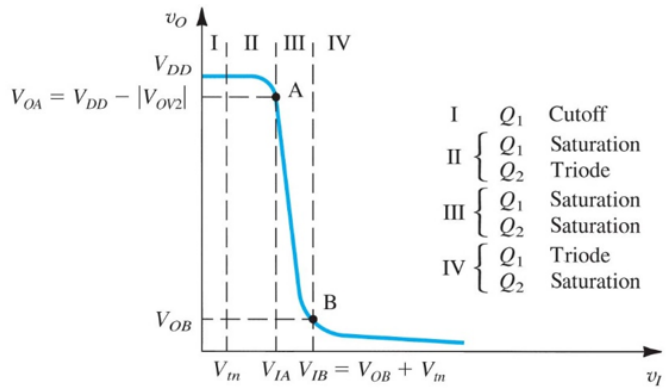
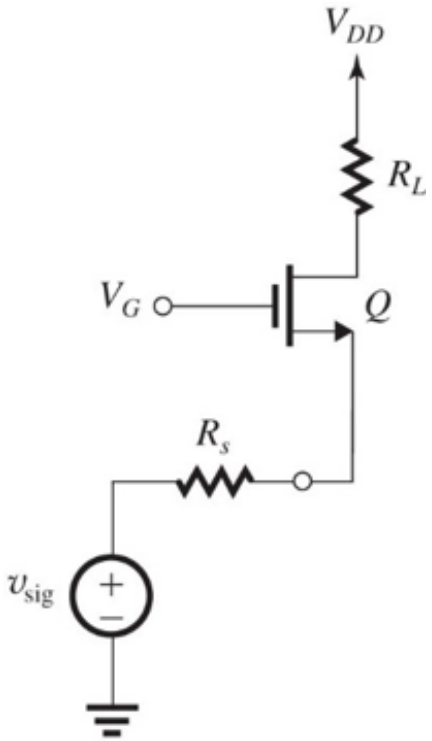


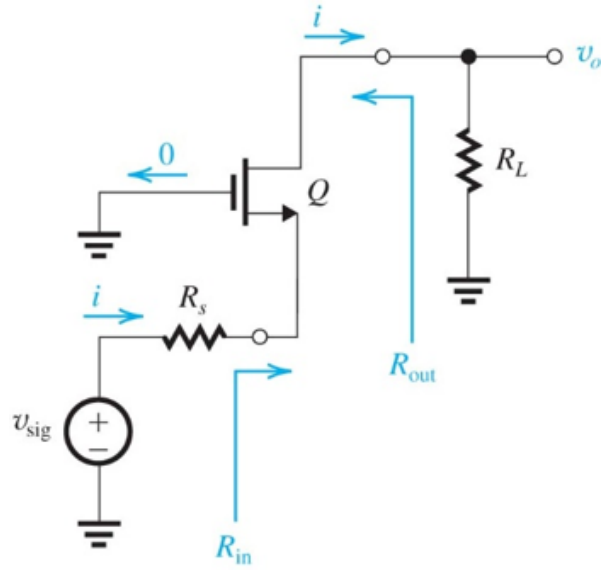
(d)

Home Assignment last week: Inverter Small Signal Analysis

CG amplifier revisited

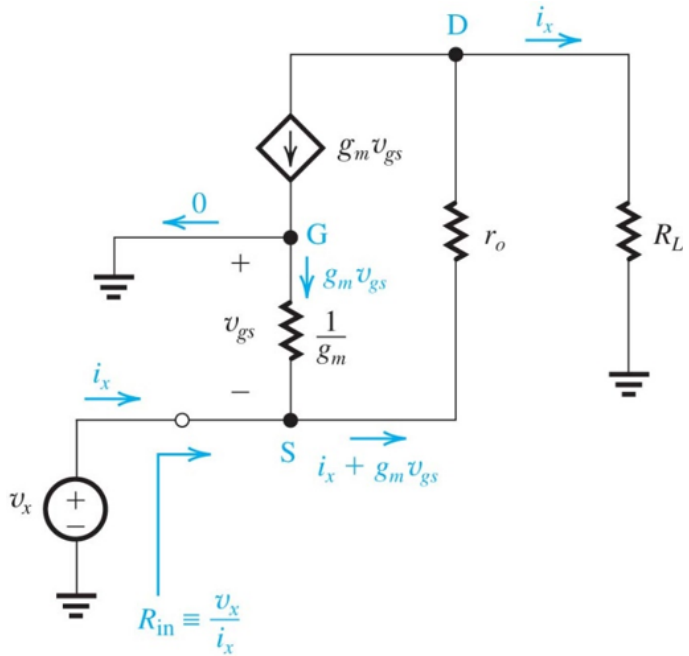


(a)



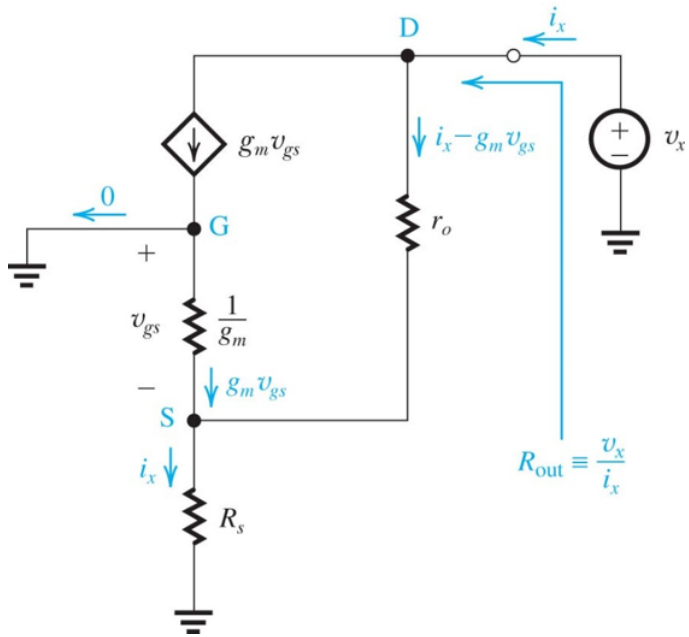
(b)

R_{in} of a CG amplifier



$$v_x = (i_x + g_m v_{gs}) r_o + i_x R_L \;\Rightarrow\; R_{in} \approx \frac{1}{g_m} + \frac{R_L}{g_m r_o} \quad (7.54)$$

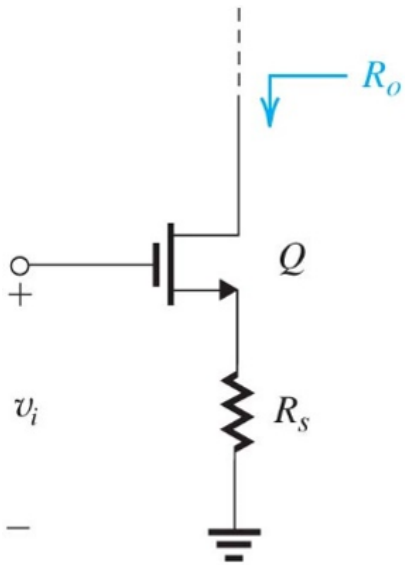
R_{out} of a CG amplifier



$$v_x = (i_x - g_m v_{gs}) r_o + i_x R_S \;\Rightarrow\; R_{out} \approx r_o + (g_m r_o) R_s \quad (7.58)$$

CS with source degeneration no R_L

Good as current source, e.g in current mirror, but not so good as amplifier.



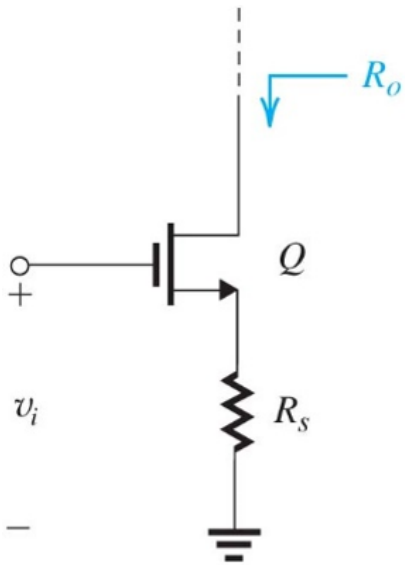
$$R_o = R_s + r_o + g_m r_o R_s$$
$$R_o \simeq (1 + g_m R_s)\, r_o$$

$$R_O \approx (1 + g_m R_S) r_o$$

$$g_m \rightarrow g_m' = \frac{g_m}{1 + g_m R_s}$$

Much higher output resistance. Still no net-increase in gain!

CS with source degeneration with R_L



$R_o = R_s + r_o + g_m r_o R_s$

$R_o \simeq (1 + g_m R_s)\, r_o$

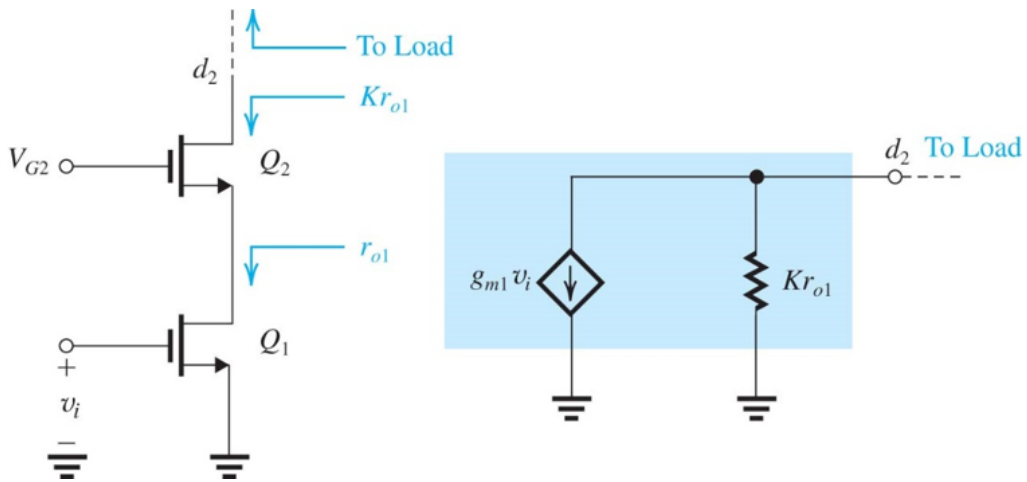
$$A_v = g'_m R_O \frac{R_L}{R_L + R_O}$$

$$\approx g_m r_o \frac{R_L}{R_L + (1 + g_m R_S) r_o}$$

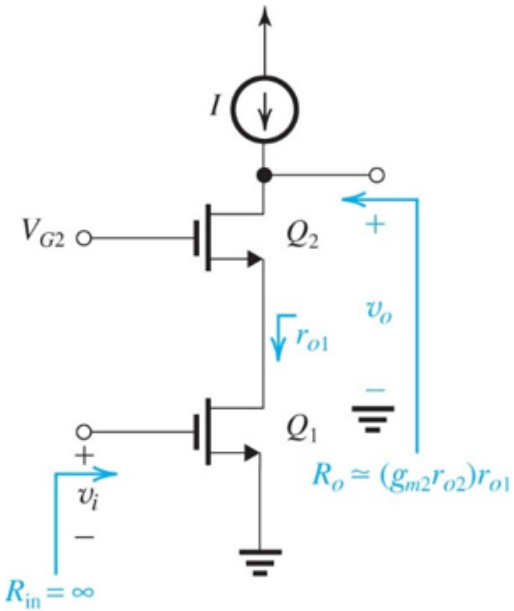
... and more degradation to A_v due to load R_L!

Cascode Amplifier

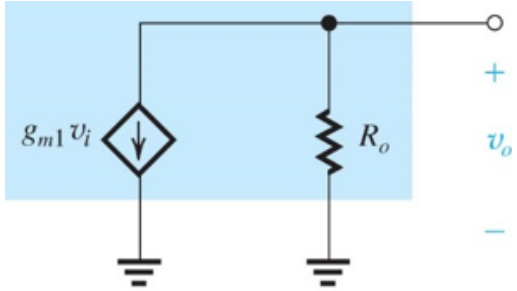
Can be looked upon as a CS and CG in series resulting in a *intrinsic* combined gain $A = g_{m1} r_{o1} g_{m2} r_{o2}$ (i.e. with a large load resistance), or a circuit where the CS serves as high quality voltage controlled current source delivering $i_d \approx g_{m1} v_i$ and the CG buffers that current to a high output resistance $\approx g_{m2} r_{o2} r_{o1}$.



Cascode Amplifier with Infinite Load Resistance

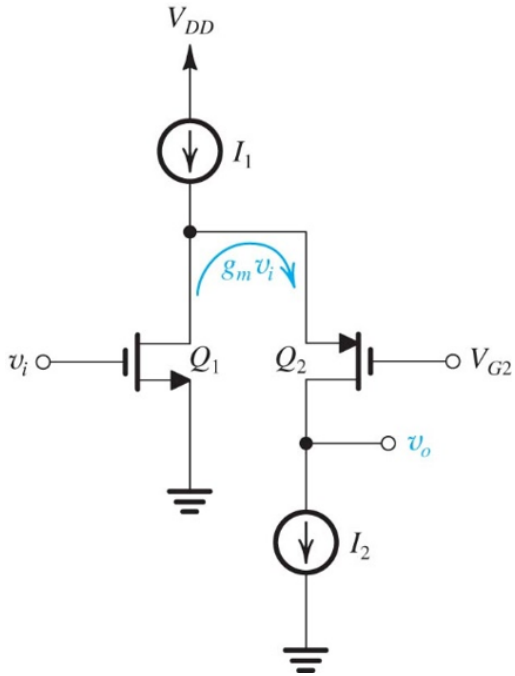


(a)

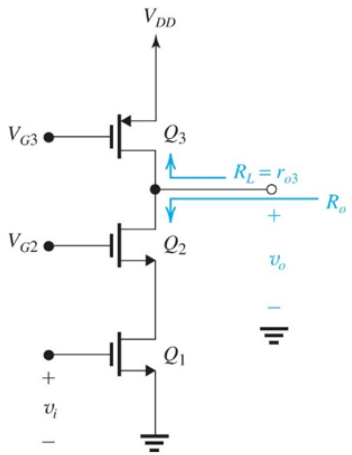


(b)

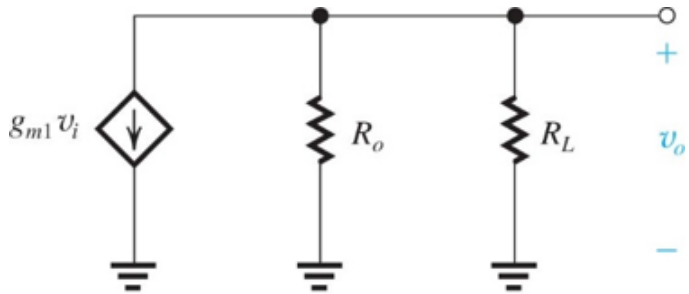
Folded Cascode with Infinite Load Resistance



Cascode Amplifier with Finite Load Resistance (1/2)



(a)

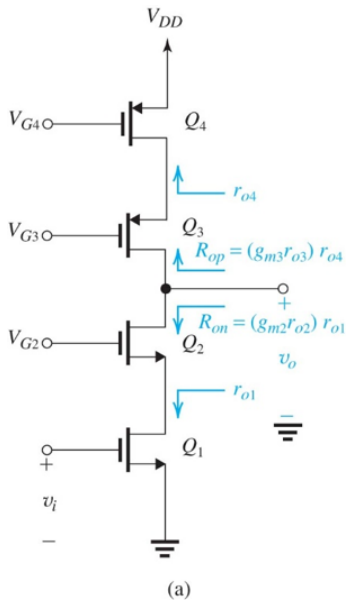


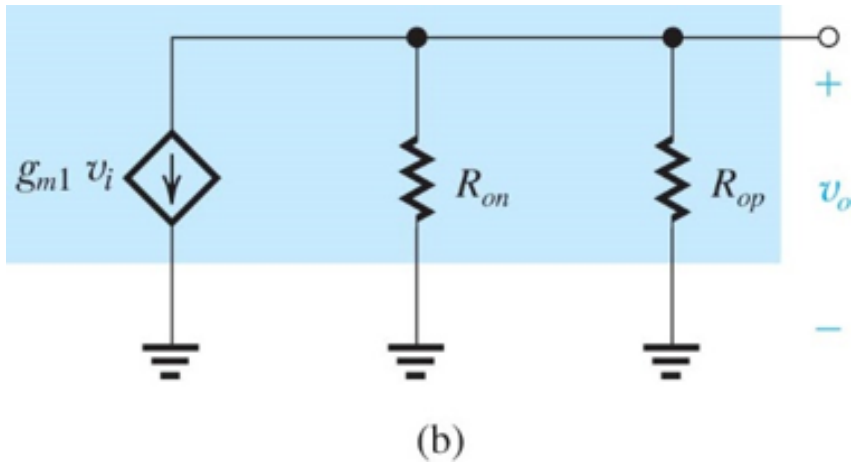
(b)

The load R_L must be of equal magnitude as R_O to get the benefit of the increased gain A_V! So here with a simple pFET we are back to square one.

Cascode Amplifier with Finite Load Resistance (2/2)

Better: employ a cascoded current source.





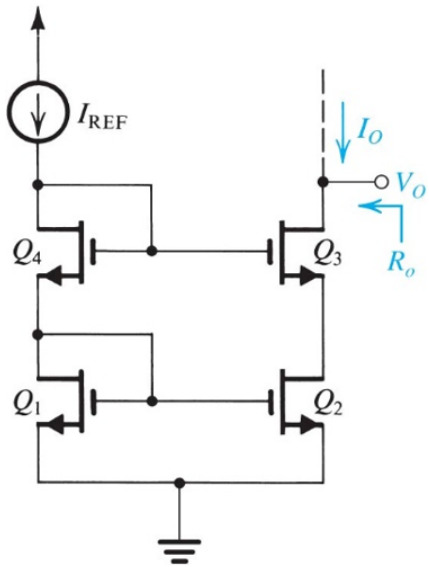
Dependency of Gain on R_L

Table 7.1 Gain Distribution in the MOS Cascode Amplifier for Various Values of R_L

Case	R_L	R_{in2}	R_{d1}	A_{v1}	A_{v2}	A_v
1	∞	∞	r_o	$-g_m r_o$	$g_m r_o$	$-(g_m r_o)^2$
2	$(g_m r_o) r_o$	r_o	$r_o/2$	$-\frac{1}{2}(g_m r_o)$	$g_m r_o$	$-\frac{1}{2}(g_m r_o)^2$
3	r_o	$\frac{2}{g_m}$	$\frac{2}{g_m}$	-2	$\frac{1}{2}(g_m r_o)$	$-(g_m r_o)$
4	0	$\frac{1}{g_m}$	$\frac{1}{g_m}$	-1	0	0

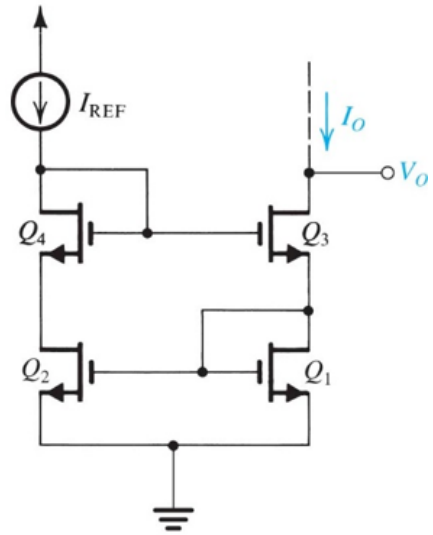
Content

Cascode Current Mirror



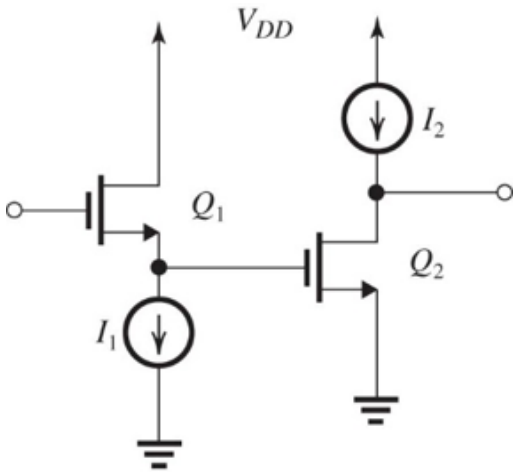
Increased output impedance, but quite a bit of output voltage headroom necessary ...

Modified Wilson MOS Current Mirror



(c)

A CD-CS Amplifier



(b)

Larger bandwidth than simple CS amplifier (explained later in chapter 9).