



上海科技大学
ShanghaiTech University

EE115 Analog Circuits IC AMP: Common Gate Cell

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Outline



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- Common-Gate Amplifiers
 - Increase the Gain of Basic Cell
 - Common-Gate Amplifiers as Current Buffers
- Reading: SEDTRA/SMITH book pages 527-539



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Review: Basic MOSFET Current Source



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- Neglecting channel length modulation

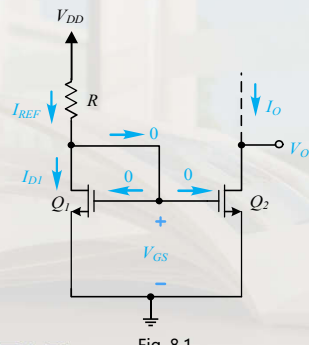


Fig. 8.1

$$I_{D1} = \frac{1}{2} k'_n \left(\frac{W}{L} \right)_1 (V_{GS} - V_{tn})^2$$

$$I_{D1} = I_{REF} = \frac{V_{DD} - V_{GS}}{R}$$

$$I_o = I_{D2} = \frac{1}{2} k'_n \left(\frac{W}{L} \right)_2 (V_{GS} - V_{tn})^2$$

$$\frac{I_o}{I_{REF}} = \frac{(W/L)_2}{(W/L)_1}$$



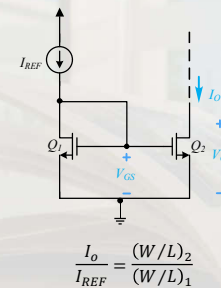
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Review: MOS Current Source



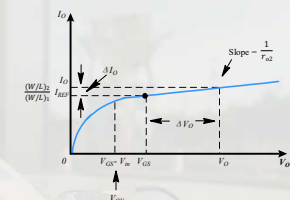
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- Neglecting channel length modulation



$$\frac{I_o}{I_{REF}} = \frac{(W/L)_2}{(W/L)_1}$$

- Considering channel length modulation

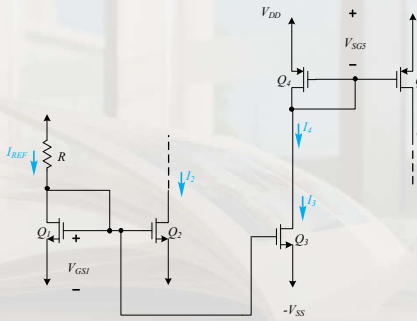


$$I_o = \frac{(W/L)_2}{(W/L)_1} I_{REF} \left(1 + \frac{V_{DS} - V_{GS}}{V_{A2}} \right)$$



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Review: MOS Current Steering Circuits



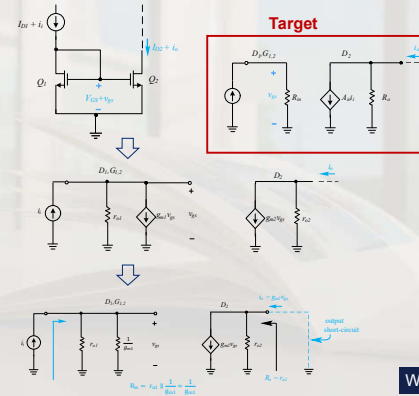
$$I_2 = I_{REF} \frac{(W/L)_2}{(W/L)_1}$$

$$I_3 = I_{REF} \frac{(W/L)_3}{(W/L)_1}$$

$$I_4 = I_3$$

$$I_5 = I_4 \frac{(W/L)_5}{(W/L)_4}$$

Review: Small-Signal Analysis



$$R_{in} = r_{o1} \parallel \frac{1}{g_{m1}} \cong \frac{1}{g_{m1}}$$

$$R_o = r_{o2}$$

$$A_{is} \equiv \left. \frac{i_o}{i_i} \right|_{v_{d2}=0} = \frac{g_{m2}v_{gs}}{i_i}$$

$$v_{gs} = i_i R_{in} = \frac{i_i}{g_{m1} + \frac{1}{r_{o1}}}$$

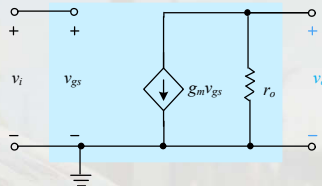
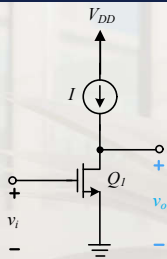
$$A_{is} = \frac{g_{m2}}{g_{m1} + \frac{1}{r_{o1}}}$$

$$A_{is} = \frac{(W/L)_2}{(W/L)_1} \frac{1}{1 + 1/(g_{m1}r_{o1})}$$

Why current mirror is an excellent current amplifier? 6/15

Review: Basic Gain Cells w/ Ideal Current Source Load

Ideal Current Source Load



$$R_{in} = \infty$$

$$A_{vo} = -g_m r_o$$

$$R_o = r_o$$

Intrinsic gain

$$g_m = \frac{I_D}{V_{OV}/2}$$

$$r_o = \frac{V_A}{I_D} = \frac{V_A' L}{I_D}$$

$$A_o = g_m r_o = \frac{V_A}{V_{OV}/2} = \frac{2V_A' L}{V_{OV}}$$

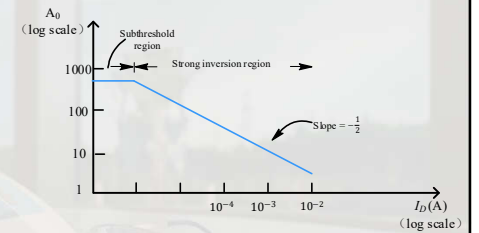
Review: Intrinsic Gain $g_m r_o$

MOSFET

$$g_m = \sqrt{2\mu_n C_{ox}(W/L)} \sqrt{I_D}$$

$$r_o = \frac{V_A}{I_D} = \frac{V_A' L}{I_D}$$

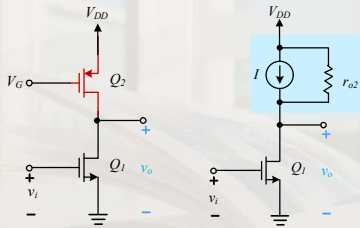
$$A_o = g_m r_o = \frac{V_A' \sqrt{2(\mu_n C_{ox})(WL)}}{\sqrt{I_D}}$$



Smaller current gives higher intrinsic gain, but paid by smaller g_m and bandwidth.

Review: Output Resistance of Current Source Load

Current source loaded/active loaded



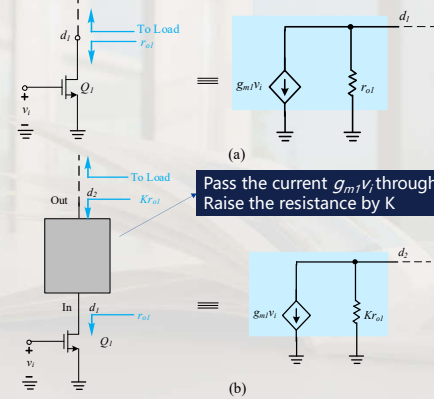
$$I = \frac{1}{2} (\mu_p C_{ox}) \left(\frac{W}{L} \right)_2 [V_{DD} - V_G - |V_{tp}|]^2$$

$$r_{o2} = \frac{|V_{A2}|}{I}$$

$$A_v \equiv \frac{v_o}{v_i} = -g_{m1}(r_{o1} || r_{o2})$$

$$A_v = -\frac{1}{2} g_m r_o$$

How To Increase Voltage Gain?

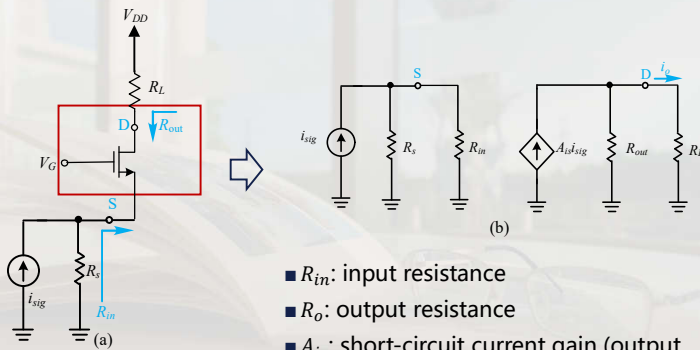


■ **Current buffer:** passes current **but** raises resistance level

- Low **input resistance**
- Unity **current gain**
- High **output resistance**

CG, CS, CD, which circuit has the best current buffer performance?

Common Gate Amplifier



- R_{in} : input resistance
- R_o : output resistance
- A_{is} : short-circuit current gain (output grounded)

Input Resistance of CG Amplifier

$$R_{in} \equiv \frac{v_x}{i_x}$$

According to KVL & KCL

$$v_x = (i_x + g_m v_{gs}) r_o + i_x R_L$$

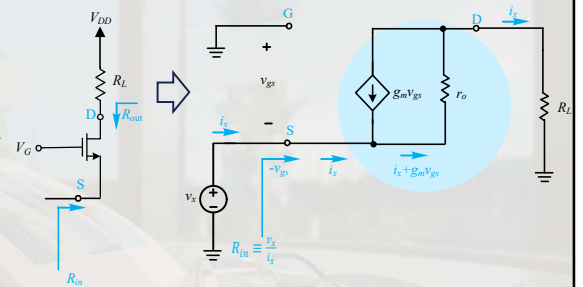
$$= (i_x - g_m v_x) r_o + i_x R_L$$

$$R_{in} = \frac{r_o + R_L}{g_m r_o + 1}$$

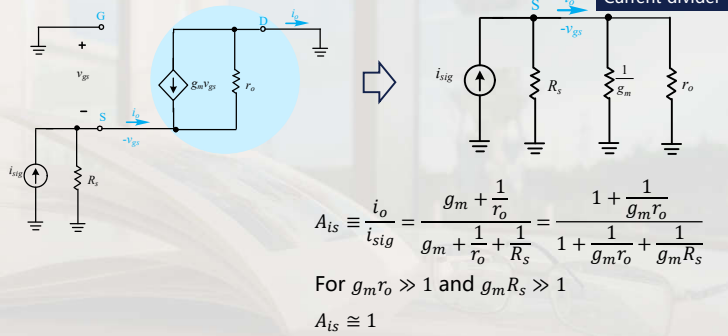
For $g_m r_o \gg 1$

$$R_{in} \cong \frac{1}{g_m} + \frac{R_L}{g_m r_o}$$

Low R_{in} : load impedance is transformed to the input by dividing by the intrinsic gain.



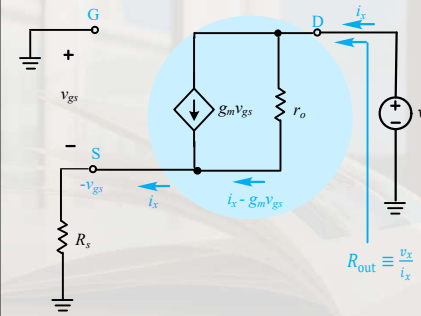
Short-Circuit Current Gain of CG Amplifier



Unity current gain

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Output Resistance of CG Amplifier



According to KVL & KCL

$$v_x = (i_x - g_m v_{gs}) r_o + i_x R_s$$

$$v_{gs} = -i_x R_s$$

$$R_{out} \equiv \frac{v_x}{i_x} = r_o + R_s + g_m r_o R_s$$

$$= r_o + (1 + g_m r_o) R_s$$

For $g_m r_o \gg 1$

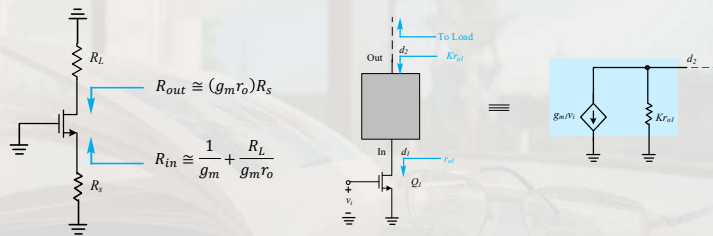
$$R_{out} \approx (g_m r_o) R_s$$

High R_{out} : source impedance is transformed to the output by multiplying intrinsic gain.

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Impedance Transformation of CG Amplifier

- R_s transformed to the output by multiplying by the intrinsic gain.
- R_L transformed to the input by dividing by the intrinsic gain.



CG Amplifier is an ideal current buffer load to boost voltage gain!

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