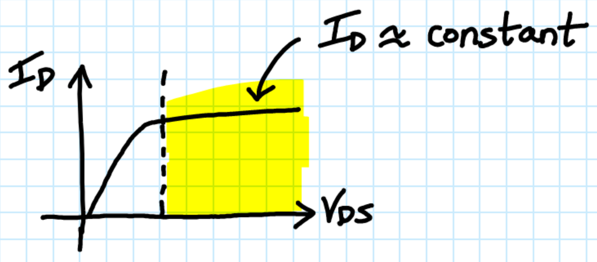
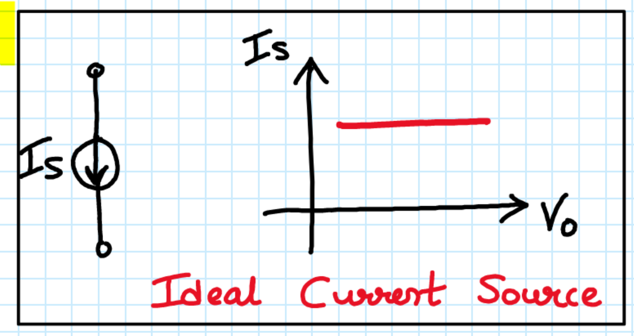
AVLSI 8.1

25 July 2021 00:47

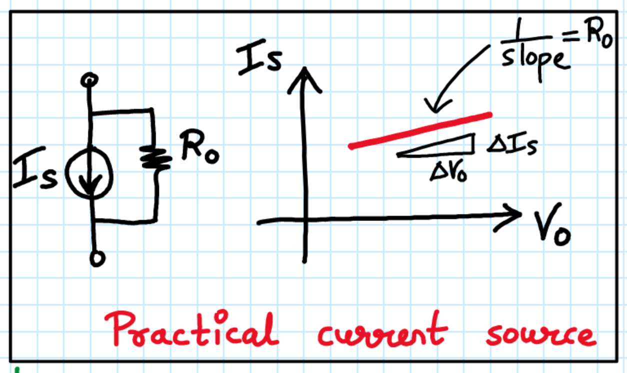
Todays topic:
MOSFET as current source

✱ Building current source using MOSFET:

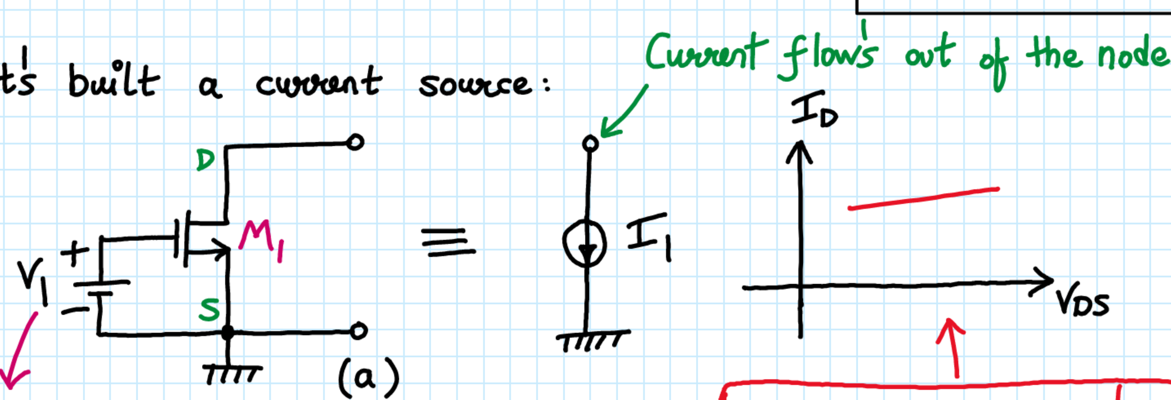




① When a MOSFET is in saturation it's current is relatively constant

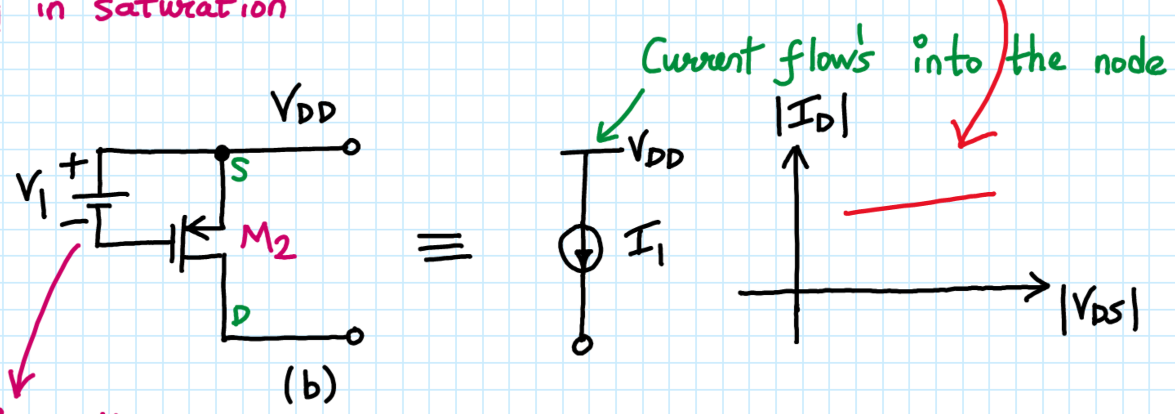


② Let's built a current source:



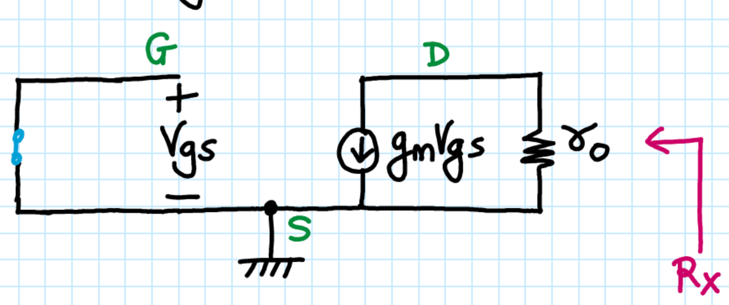
Bias voltage such that
↓
M_1 in saturation

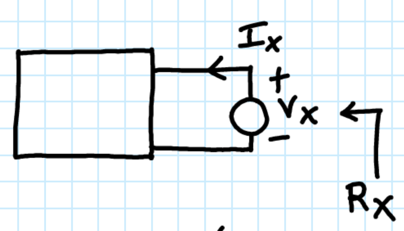
Good approximations to a current source



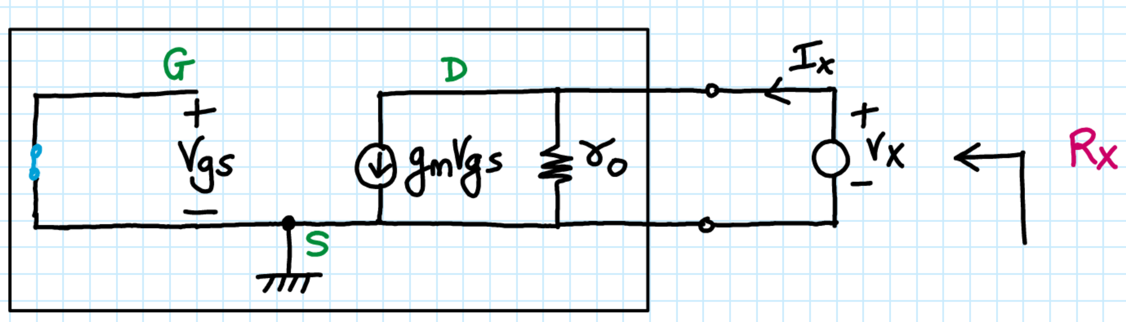
Bias voltage such that
↓
M_2 in saturation

③ Small-signal Model: for (a) Calculate port impedance:





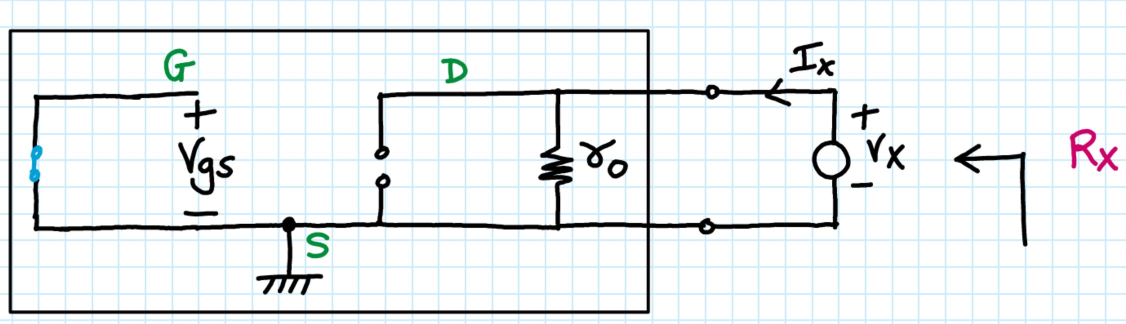
$$R_X = \frac{V_X}{I_X}$$



$V_{gs} = 0 \rightarrow g_mV_{gs} = 0$

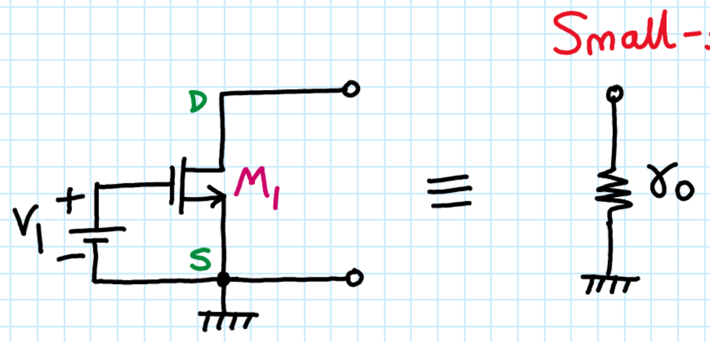
i.e g_mV_{gs} current source become reduntant

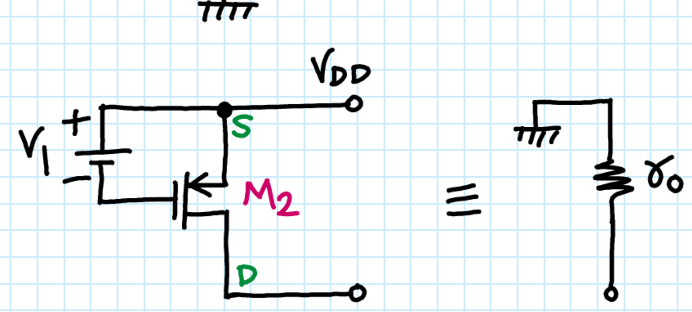
i.e Circuit reduces to



$$\boxed{\frac{V_X}{I_X} = r_o = R_X}$$

Small-signal model





④ **Key points**: Any time we see a MOSFET operating as a constant current source, we can for our small signal purpose's → can replace it with a single resistance equal to r_o

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Q1. Assuming that M_1 in fig 8.1 is biased in saturation, calculate the small signal voltage gain of the circuit

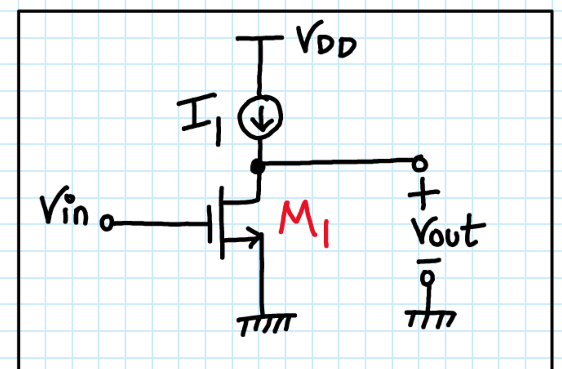
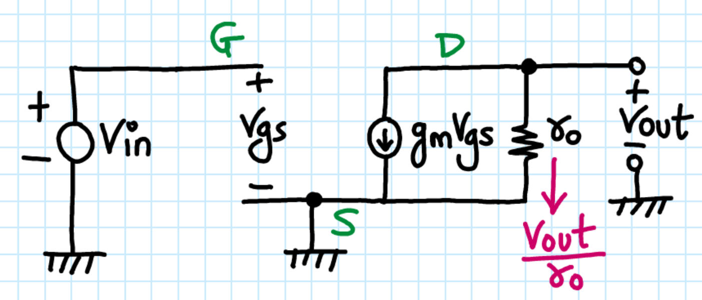


fig 8.1

I_1 is constant and ideal

Solution:

① Small signal model of circuit



(Since I_1 is constant → for small signal analysis, $I_1 = 0$ → zero current source → open circuit)

② $V_{in} = V_{gs}$

③ KCL at 'D' node gives,

$$g_mV_{gs} + \frac{V_{out}}{r_o} = 0$$

i.e $g_mV_{in} + \frac{V_{out}}{r_o} = 0$

i.e $\frac{V_{out}}{V_{in}} = -g_mr_o$

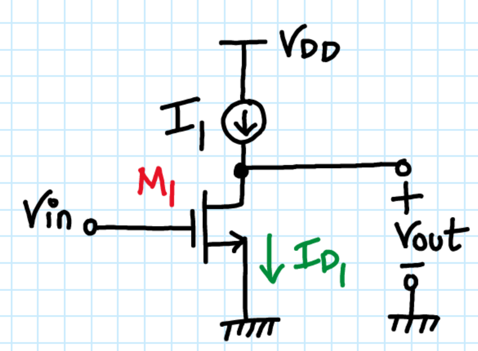
i.e $\boxed{A_V = -g_mr_o}$ .....(1.1)

Small-signal voltage gain

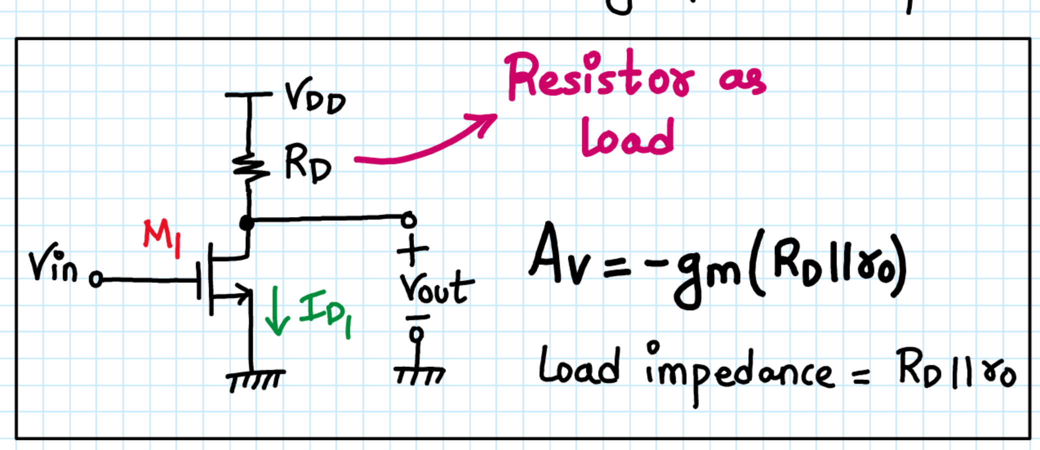
I_1 is a current source and ideally has an infinite impedance

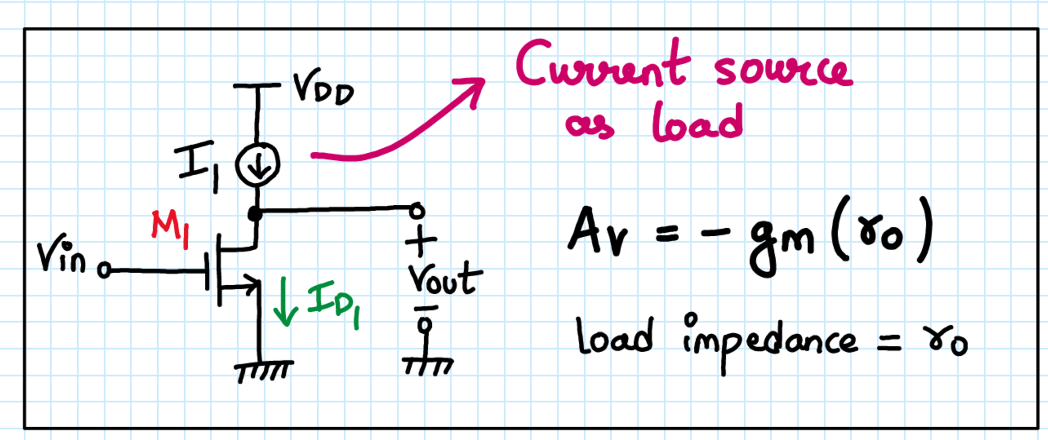
④ $A_V = -g_mr_o$ is the maximum gain of this amplifier

⑤ "g_mr_o" is called the "intrinsic gain" of a MOSFET transistor → represents the maximum voltage gain that can be achieved using a single MOSFET device



⑥ **Important Conclusion:** To maximize the voltage gain A_V → we must maximize the (small-signal) load impedance



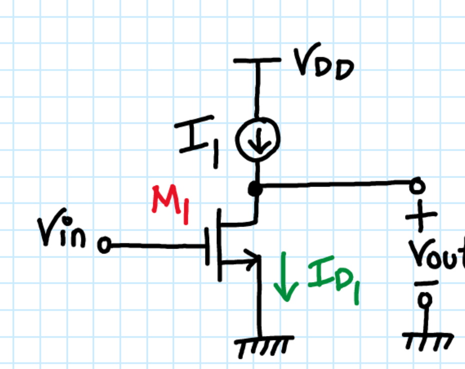


⑦ How can V_{in} change if I_1 is constant ?

$$I_{D_1} = \frac{1}{2}\mu_nC_{ox}\frac{W}{L}(V_{GS}-V_{th})^2(1+\lambda V_{DS})$$

$V_{GS} = V_{in}$ and $V_{DS} = V_{out}$

$$\boxed{I_{D_1} = \frac{1}{2}\mu_nC_{ox}\frac{W}{L}(V_{in}-V_{th})^2(1+\lambda V_{out}) = I_1} \quad .....(1.2)$$



→ From equation (1.2), as V_{in} changes, V_{out} also changes to keep I_1 constant

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