Final examination

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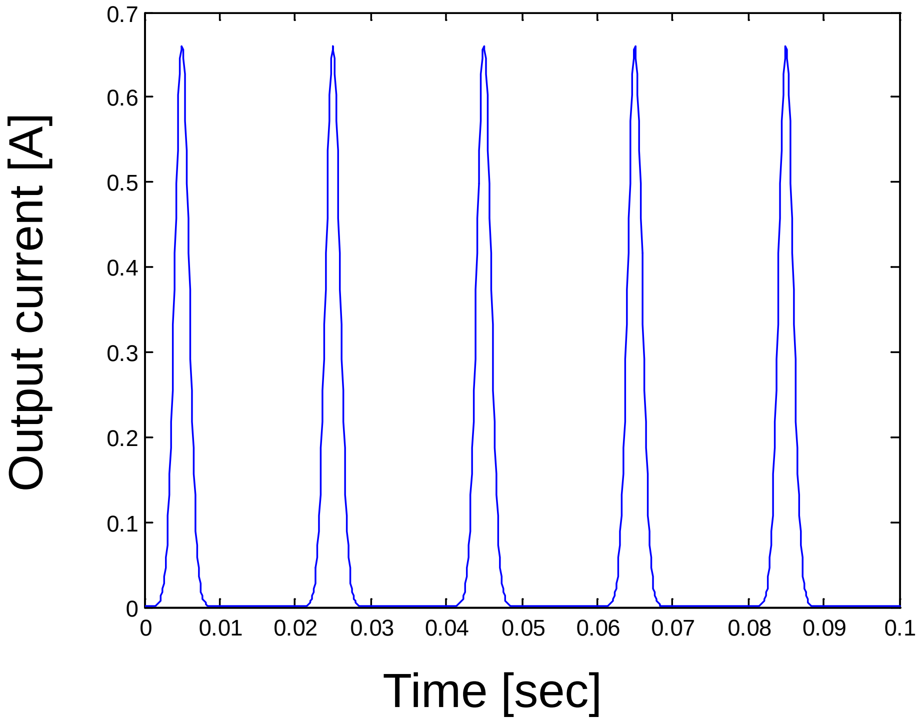
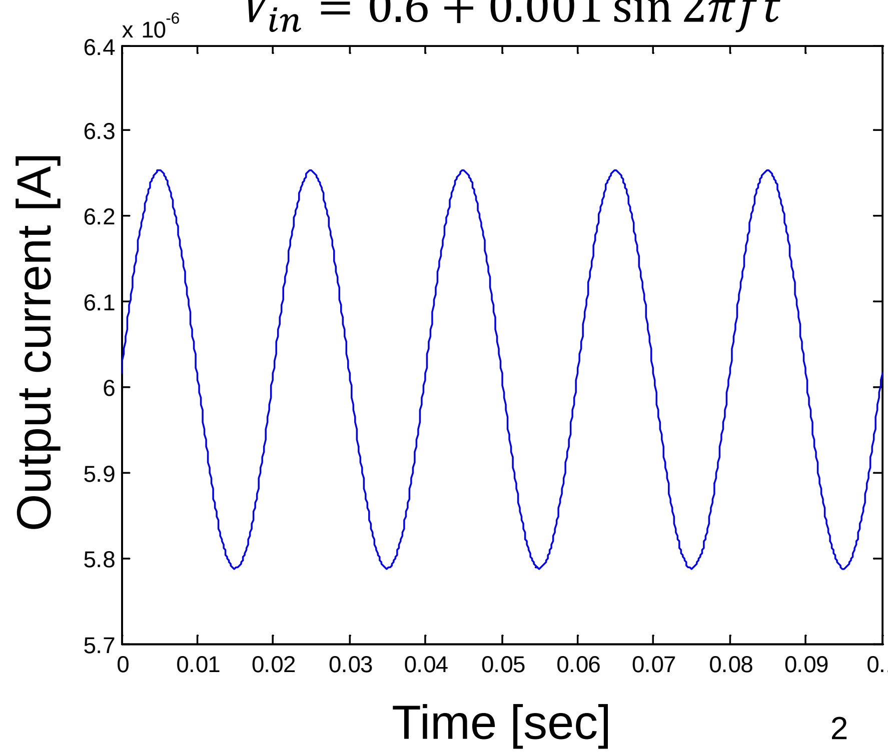
Problem1

- A nonlinear system, $I_{out} = I_s \exp \frac{V_{in}}{V_T}$, is considered.
  - Two cases (0.3 V swing and 1 mV swing) are shown below.
  - Describe those output currents in the frequency domain.

$V_{in} = 0.6 + 0.3 \sin 2\pi f t$

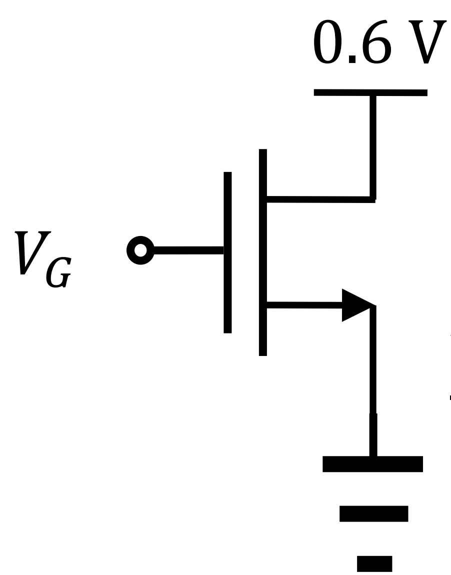


$V_{in} = 0.6 + 0.001 \sin 2\pi f t$



Problem2

- Consider a NMOSFET.
  - Neglect the channel length modulation.
  - 1. Draw its transconductance up to $V_{GS} = 1.8\ \mathrm{V}$. Use the IV model studied in the class room.
  - 2. The above answer is not fully consistent with the realstic results. Especially, it goes wrong for high V_{GS} values. Explain why.



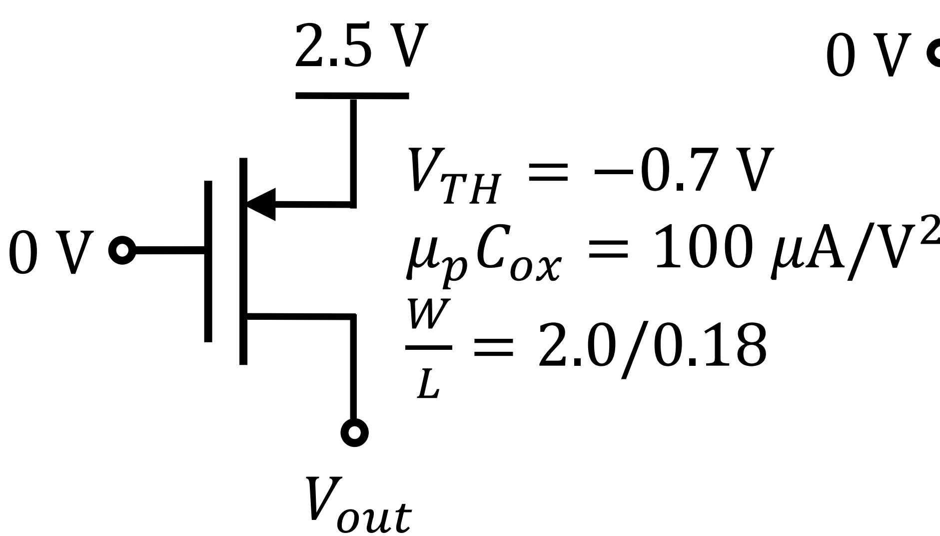
$V_{TH} = 0.6\ \mathrm{V}$

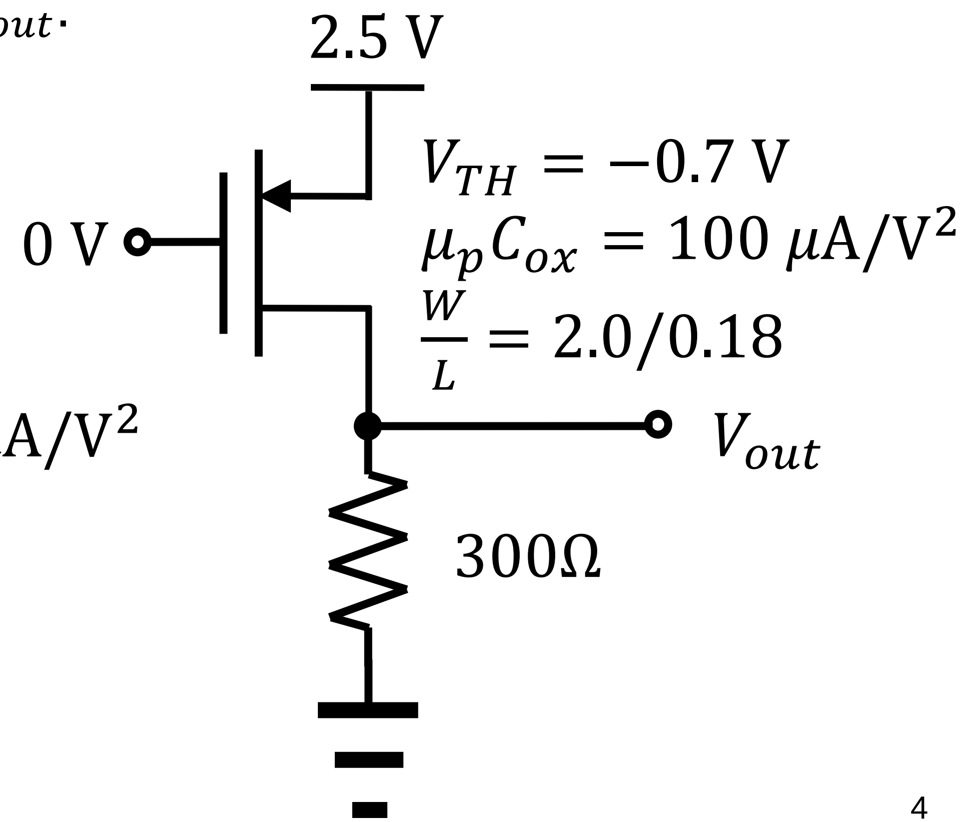
$\mu_n C_{ox} = 300\ \mu\mathrm{A/V^2}$

$\frac{W}{L} = 2.0/0.18$

Problem3

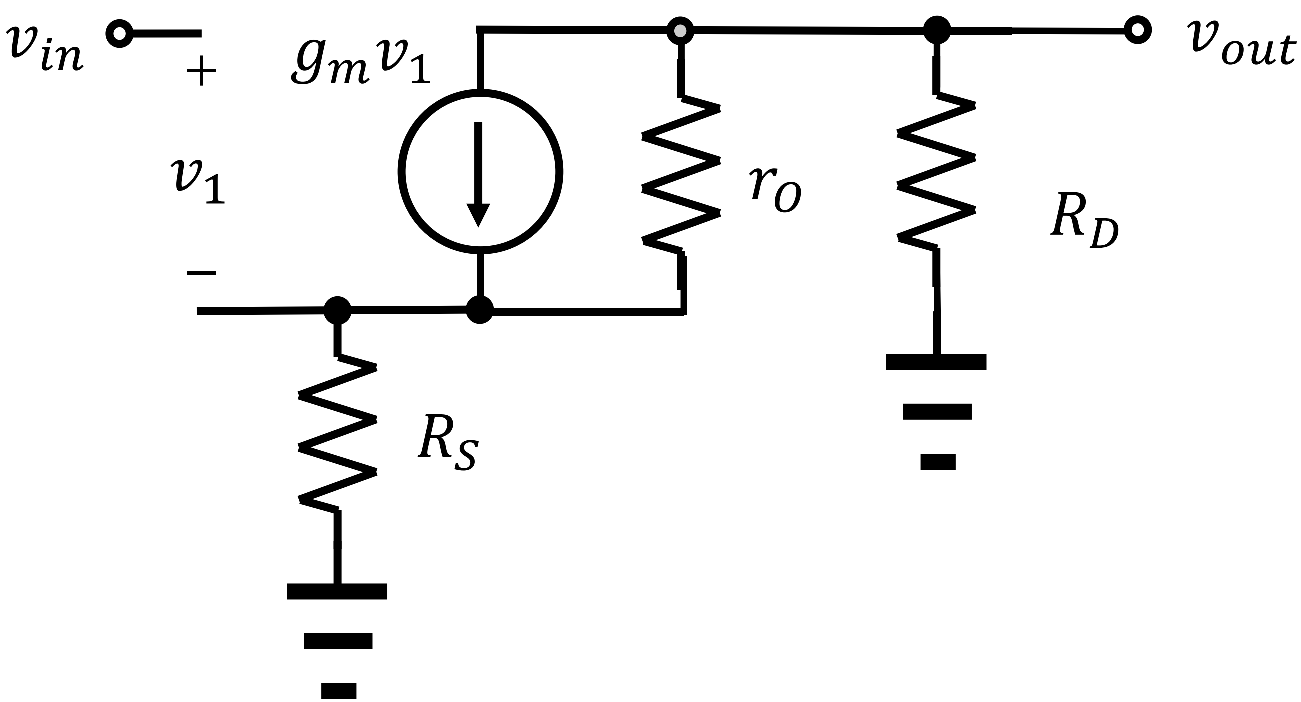
- Consider the following circuit. (Neglect the channel length modulation.)
  - 1. (Left figure) Draw the source current as a function of V_{out}.
  - 2. (Right figure) Calculate V_{out}.





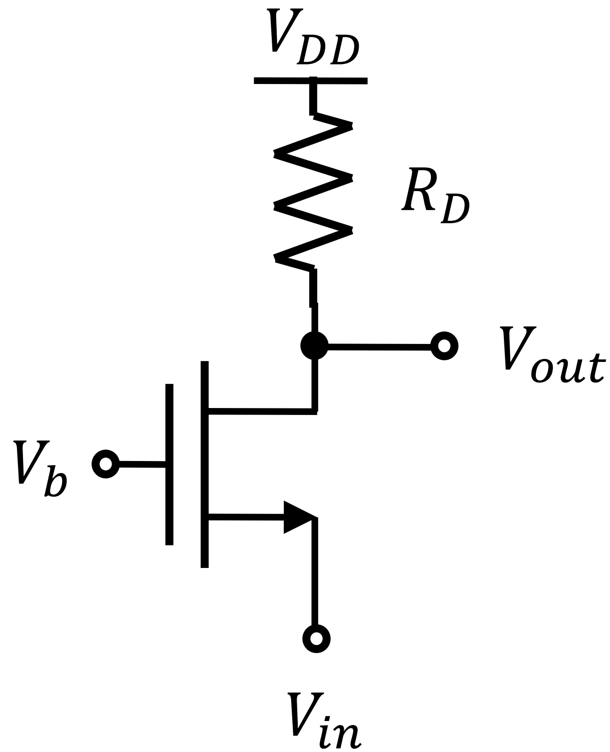
Problem4

- A small-signal model of the source-degenerated CS amplifier is shown.
  - Derive the voltage gain with the channel length modulation.
  - (If it is difficult, you may try without the channel length modulation for partial credit.)



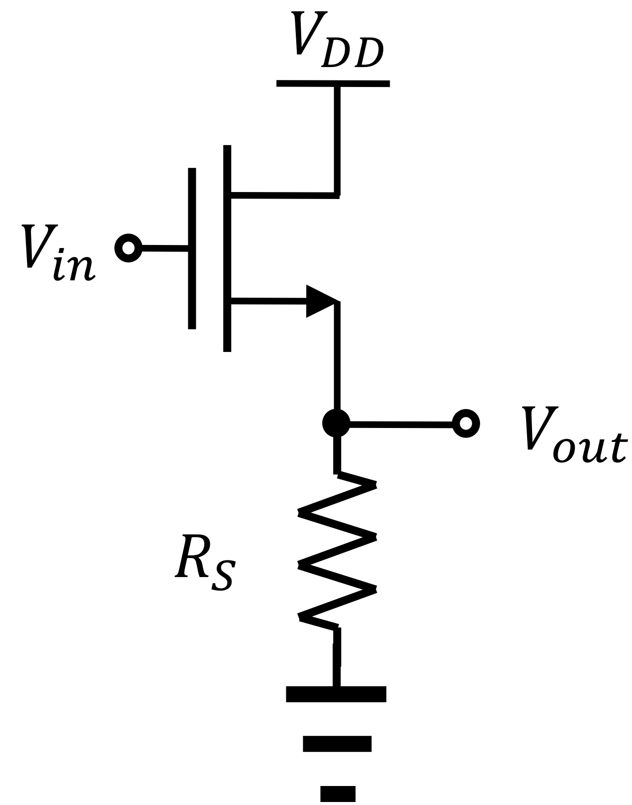
Problem5

- Consider a common-gate amplifier.
  - 1. Calculate the input impedance, when the channel length modulation is neglected.
  - 2. Repeat again with the channel length modulation.



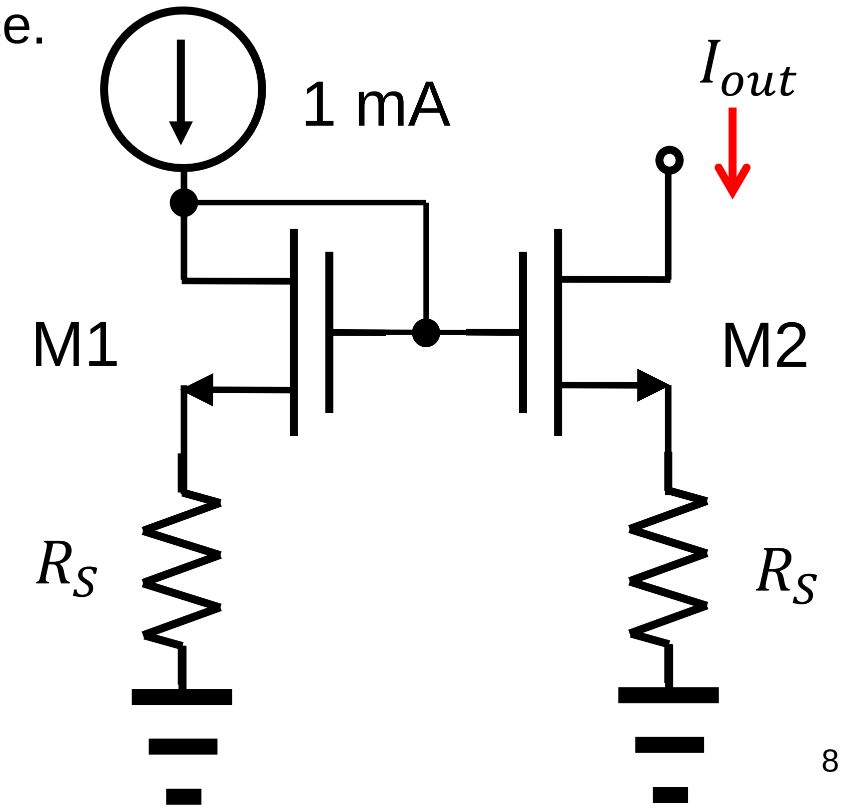
Problem6

- A source follower is shown.
  - Consider the channel length modulation.
  - 1. Calculate the voltage gain.
  - 2. Calculate the output resistance.



Problem7

- Consider the following circuit.
  - Two transistors, M1 and M2, are identical.
  - 1. What is the output current, approximately? (Assume that M2 is in the saturation mode.)
  - 2. Express the output impedance.



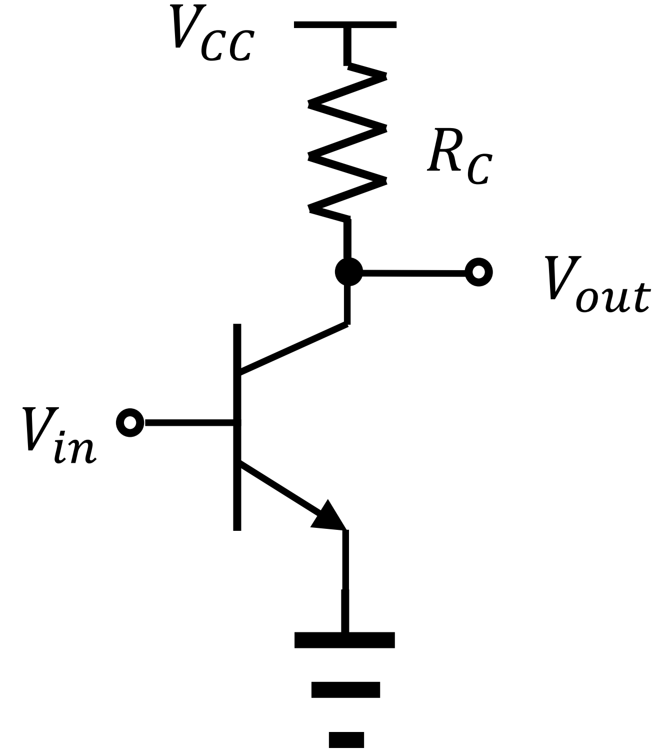
Problem8

- Consider a bipolar junction transistor.
  - In the BJT, $I_S = 10^{-15}\ \mathrm{A}$.
  - The Early voltage is 100 V.
  - Also use the approximate relation, $\exp \frac{60\ \mathrm{mV}}{V_T} \approx 10$.
  - Draw the collector current as a function of the collector-emitter voltage for $V_{BE} = 0.72\ \mathrm{V}$.
  - Explicitly show the current values as much as you can.

(Approximate graph is allowed.)

Problem9

- Consider a common-emitter amplifier.
  – 1. Express g_m and r_O of the bipolar junction transistor as a function of the collector current.
  – 2. Show that the voltage gain becomes insensitive to I_C, when we have a very large R_C.



Problem10

- G-SPICE input file for a circuit is shown.
  - 1. Draw the circuit diagram.
  - 2. Calculate the voltage of node#2.

(Approximate solutions are allowed.)

```
tstep = 1e-3 ;
tnum = 1000 ;
vdc = 1 ;
vdc_value = 1.8 ;
vdc_node1 = 0 ;
vdc_node2 = 3 ;
vsweep = 1 ;
vsweep_value = 1.8 ;
vsweep_num = 100 ;
vsweep_node1 = 0 ;
vsweep_node2 = 1 ;
mos[0] = 1 ; (NMOS)
mos_type[0] = 0 ;
mos_vt0[0] = 0.4 ;
mos_kp[0] = 100e-6 ;
mos_w[0] = 2.0 ;
mos_l[0] = 0.18 ;
mos_lambda[0] = 0.0 ;
mos_node1[0] = 0 ; (S)
mos_node2[0] = 1 ; (G)
mos_node3[0] = 2 ; (D)
r[0] = 1 ;
r_value[0] = 5e3 ;
r_node1[0] = 2 ;
r_node2[0] = 3 ;
```

Problem11

- NMOS inverter vs. CMOS inverter
  - 1. For each inverter, sketch the drain current as a function of the input voltage.
  - 2. Compare the results from the viewpoint of the standby power.