Problem Set 2 - Small Signal Model

Question 1

An NMOS transistor is operated with a small v_{DS} voltage in the triode region and the drain source resistance is measured to be r_{DS}. What will be the new r'_{DS} under each of the following situations? (give r'_{DS} relationship to r_{DS}).
Assume the only change is the one(s) discussed in each situation.
(a) The overdrive voltage is increased by a factor of 1.5.
(b) The transistor width is increased by a factor of 1.8.
(c) The transistor width and length are both increased by a factor of 3.
(d) The transistor gate oxide thickness is reduced by a factor of 2.

Answer

(a) $r'_{DS} = r_{DS}/1.5$
(b) $r'_{DS} = r_{DS}/1.8$
(c) $r'_{DS} = r_{DS}$
(d) $r'_{DS} = r_{DS}/2$

Question 2

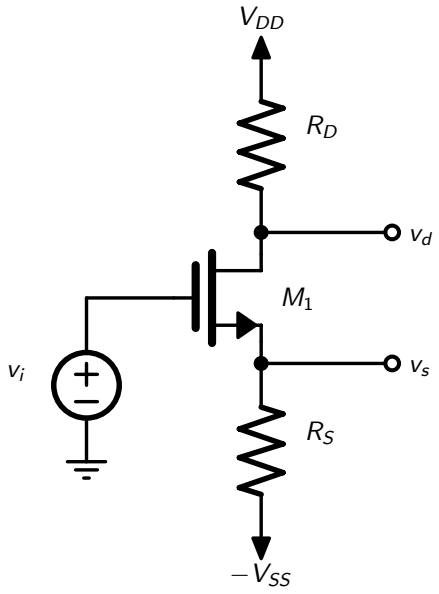
Consider a CMOS technology with the following parameters:
NMOS: $V_{tn} = 0.4\text{V}$; $\mu_n C_{ox} = 240\mu\text{A/V}^2$; $\lambda'_n = 40\text{nm/V}$
(a) For an NMOS transistor with $W_n = 2\mu\text{m}$ and $L_n = 200\text{nm}$, find I_{Dn} when the overdrive voltage is 0.3V and $V_{DS} = 0.5\text{V}$. For this question, do NOT assume $\lambda = 0$.
(b) Find the value of r_o for the transistor (a)
(c) For the transistor in (a), find the change in I_{Dn} if V_{DS} is increased by 0.4V by using r_o found in (b)

Answer

(a) $I_{Dn} = 112.3\mu\text{A}$
(b) $r_o = 44.52\text{k}\Omega$
(c) $\Delta I_{Dn} = 8.986\mu\text{A}$

Question 3

For the NMOS amplifier below, replace the transistor with its T equivalent circuit and assume $\lambda = 0$. Derive expressions for small-signal voltage gains v_s/v_i and v_d/v_i given g_m for the transistor.

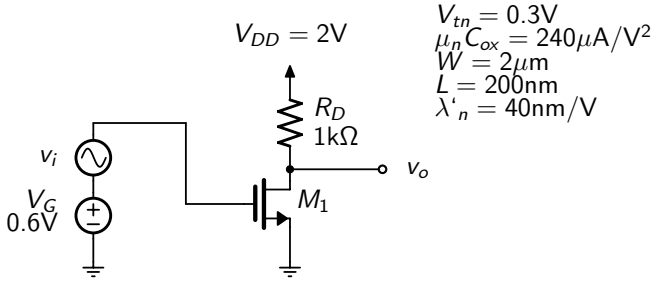


Answer

$\frac{v_s}{v_i} = \frac{R_S}{R_S+(1/g_m)}$
$\frac{v_d}{v_i} = \frac{-R_D}{R_S+(1/g_m)}$

Question 4

For the common-source amplifier shown below, find the small signal gain, v_o/v_i.

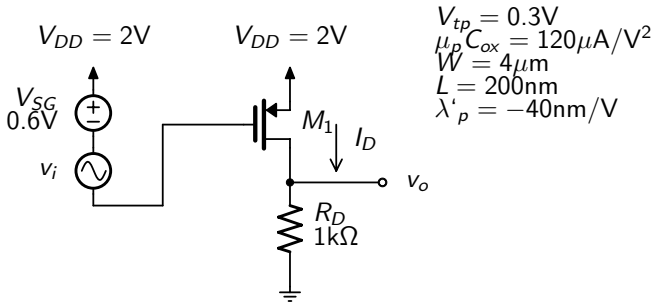


Answer

$v_o/v_i = -0.7048\text{V/V}$

Question 5

For the common-source PMOS amplifier shown below, find the small signal gain, v_o/v_i.

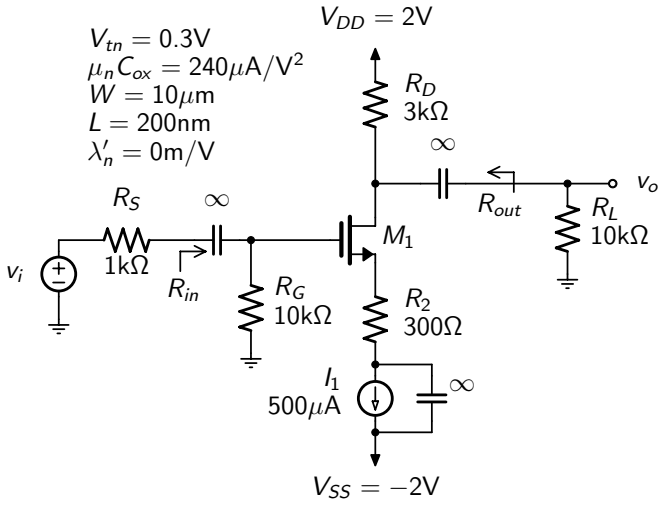


Answer

$v_o/v_i = -0.7048\text{V/V}$

Question 6

For the common-source amplifier shown below, find the small signal gain, v_o/v_i, R_{in} and R_{out}.



Answer

$v_o/v_i = -3.564\text{V/V}$
