Q1 Rizzoni Problem 11.2

The 3 terminals of an n-channel MOSFET with V_T = 1V, are at potentials of 4V, 5V, and 10V with respect to ground. Draw the circuit symbol, with appropriate voltages at each terminal, if the device is operating in the:

a. Ohmic region
b. Saturation region

Q2 Rizzoni Problem 11.3

An n-channel MOSFET with V_T = 2V has its source grounded and 3V DC source connected to its gate. Determine the state of the device if:

a. v_D = 0.5V
b. v_D = 1V
c. v_D = 5V

Q3

The operating regions of a MOSFET are cut off, ohmic and saturation.

a) Which mode would you use to implement an amplifier?
b) Which mode would you not use to implement a logic gate?

Q4

For the circuit in Fig 1, given that r_o is infinitely large,

a) Draw the small signal equivalent circuit
b) Find the input resistance
c) Derive the gain (V_{out}/V_{in}) in terms of g_m, R_S and R_D
d) If a capacitor is added in parallel to R_S to bypass it, derive the gain expression.

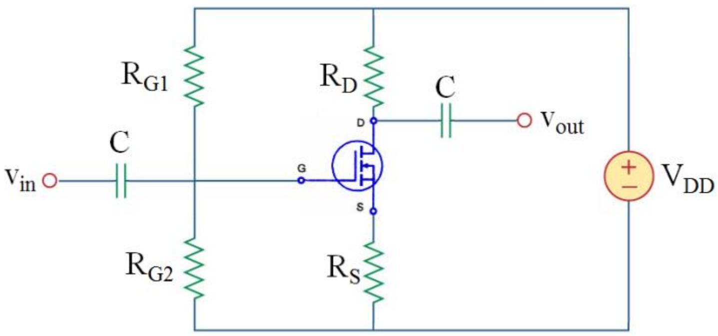


Fig 1

Q5

For the circuit in Fig 2,

a) Draw the small signal equivalent circuit
b) Find the input resistance
c) Derive the gain (V_{out}/V_{in}) in terms of g_m, r_o and R_S

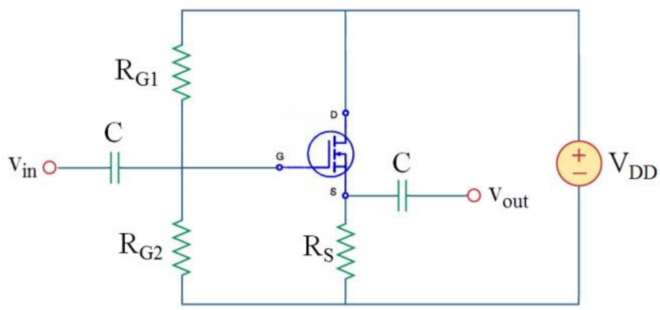


Fig 2

Answers

Q1

a) $v_G = 10V$, $v_D = 5V$, $v_S = 4V$
b) $v_G = 5V$, $v_D = 10V$, $v_S = 4V$

Q2

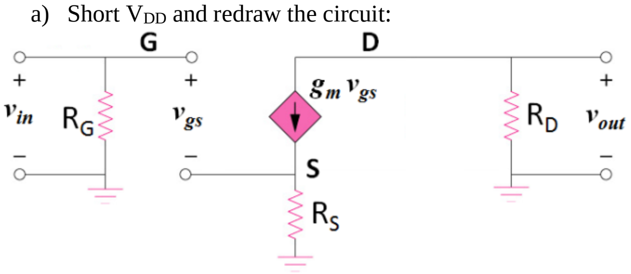
a) Triode, b) Pinch-off (Between Triode and Saturation when $v_{GD} = V_T$), c) Saturation

Q3

a) We only use saturation mode for amplifiers
b) We never use saturation mode for switches, only cutoff and triode

Q4

a) Short V_{DD} and redraw the circuit:



Remember that only AC signals are reflected in the small signal equivalent circuit and the capacitors are treated as short circuits at the working frequency.

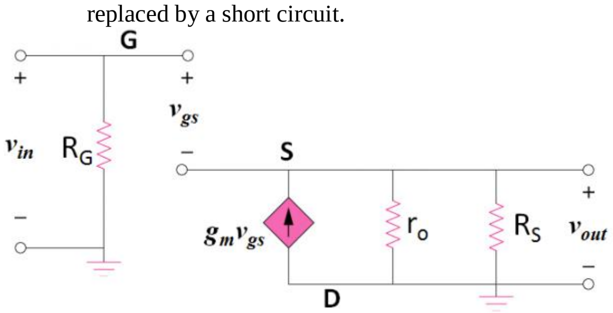
b) Input resistance = $R_G = R_{G1} \| R_{G2}$

c) Gain expression:
Current through R_S is $g_m v_{gs}$ (from S to ground)
Current through R_D is also $g_m v_{gs}$ (from ground to D)
At the input: $v_{in} = v_{gs} + g_m v_{gs} * R_s = v_{gs} * (1 + g_m * R_s)$ (1)
At the output: $v_{out} = -g_m v_{gs} * R_D$ (2)
Combine (2) and (1) to eliminate v_{gs}: $\frac{v_{out}}{v_{in}} = \square\frac{g_m R_D}{1+g_m R_S}$

d) With R_S bypassed, the gain expression becomes: $v_{out}/v_{in} = -g_m(r_o \| R_D)$

Q5

a) Short V_{DD} and redraw the circuit. Note that D is now connected directly to ground after V_{DD} is replaced by a short circuit.



Remember that only AC signals are reflected in the small signal equivalent circuit and the capacitors are treated as short circuits at the working frequency.

b) Input resistance = $R_G = R_{G1} \| R_{G2}$

c) Gain expression:

At the input: $v_{in} = v_{gs} + v_{out}$ (1)

At the output: $v_{out} = g_m v_{gs} * (r_o \| R_S)$ (2)

Combining (1) and (2) to eliminate v_{gs}:

$$\frac{v_{out}}{v_{in}} = \frac{g_m R'}{1 + g_m R'}$$, where $R' = r_o \| R_D$