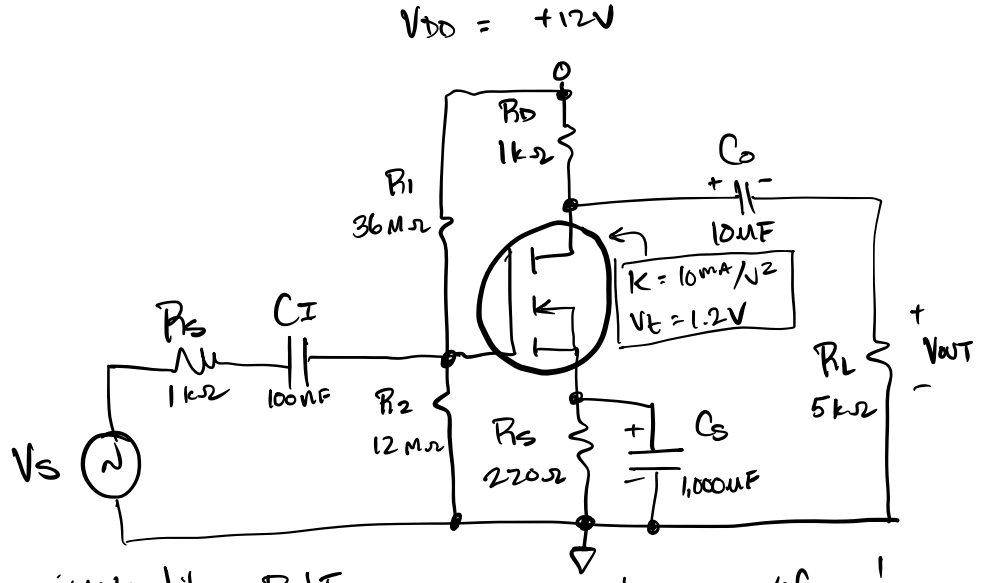
Common-Source Voltage Amplifier

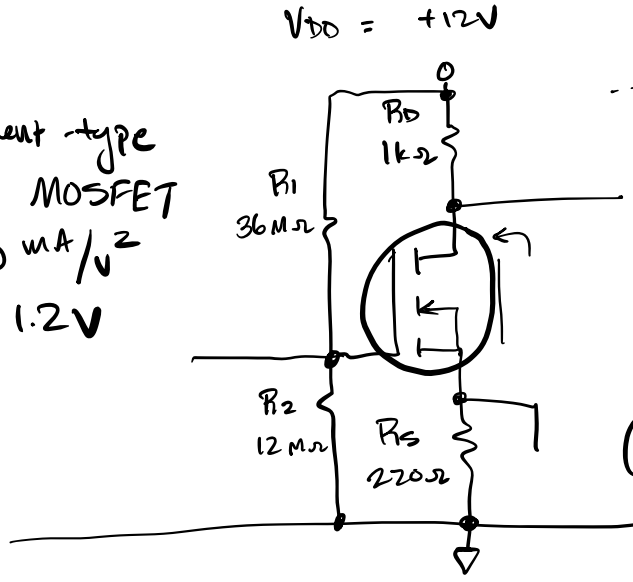


-- just like BJT common-emitter amplifier!

input: gate, output: drain, source is "grounded" by C_S.

-- first, let's consider the DC circuit and perform DC analysis

-- capacitors are considered open circuits!



~ enhancement-type n-channel MOSFET w/ $K = 10\ mA/V^2$, $V_t = 1.2V$

-- we already know

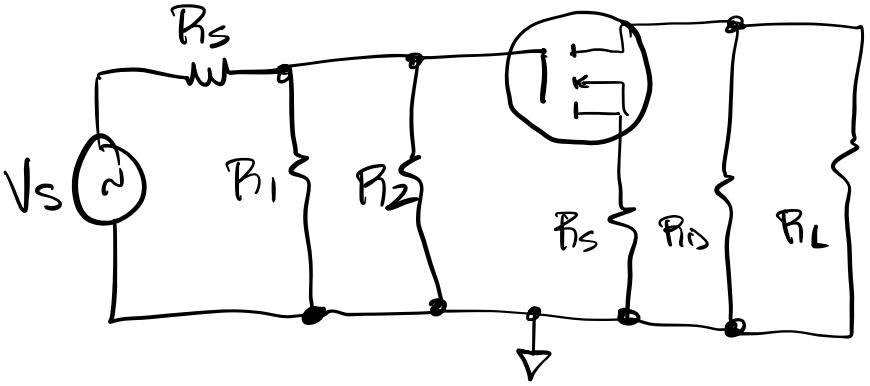
$V_{GS} = 1.905\ V$

$I_D = 4.977\ mA$

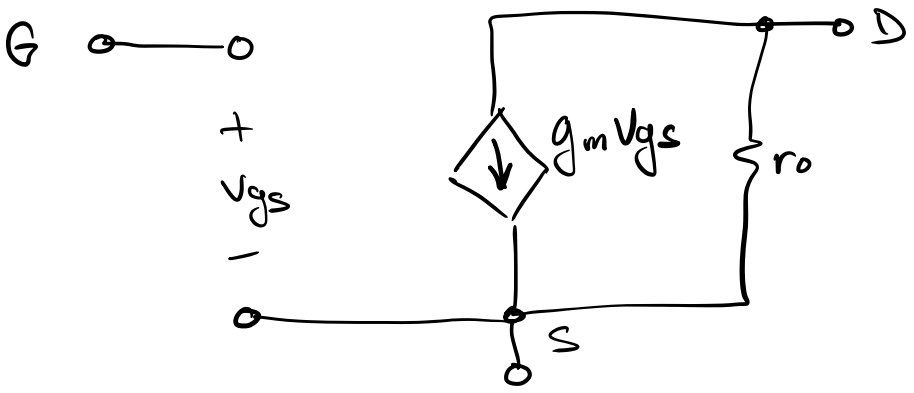
(from last lecture)

- next, we draw the mid-frequency AC circuit by considering capacitors as shorts, and V_{DD} becomes AC "ground."

MF AC Circuit:



- now we need a mid-frequency small-signal model for FET:



- doesn't this look familiar?
- there is one crucial difference -- no (↑ equivalent to small-signal) base resistance r_b, because there is no gate current!

- now we need equations for r_o and g_m:

$$r_o = \frac{|V_A|}{I_D}$$ ← yep, Early voltage!

$$g_m = \frac{2\sqrt{I_D \cdot I_{DSS}}}{|V_{GS(OFF)}|}$$ [JFET and depletion-MOSFET]

$$g_m = 2\sqrt{K I_D}$$ [enhancement MOSFET]

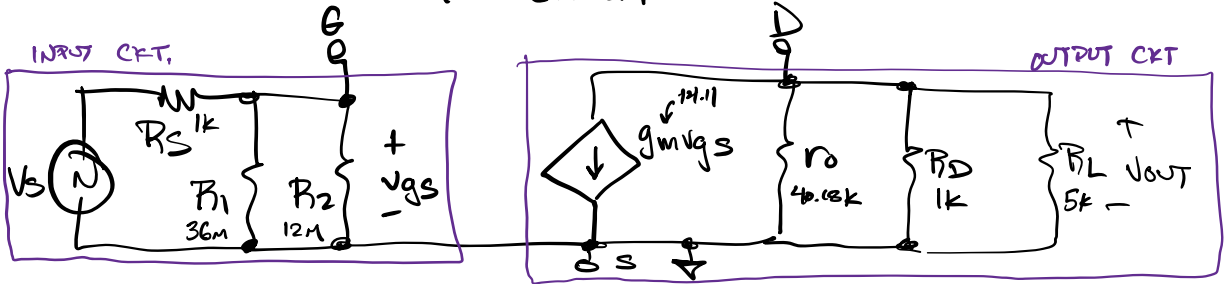
- thus, for our example, assuming $V_A = 200V$ [typical]:

$$r_o = \frac{|V_A|}{I_D} = \frac{200}{4.977} = 40.18\ k\Omega$$ (4.977 ↑ mA)

$$g_m = 2\sqrt{10 \cdot 4.977} = 14.11\ mA/V$$ ← low compared to BJTs!!! typical!!!

($\sqrt{mA/V^2 \cdot mA} = mA/V$)

- now let's combine the MF SSM with the MF AC circuit:



Input Circuit:

- just like BJT common-emitter configuration, define

$$R_G = R_1 \| R_2 = 36M \| 12M$$

$$R_G = 9\ M\Omega$$

thus, $V_{gs} = V_s \left(\frac{R_G}{R_G + R_S} \right)$

let $A_{v_1} = \frac{V_{gs}}{V_s} = \frac{R_G}{R_G + R_S} = \frac{9M}{9M + 1k} = 0.9999$

... so basically 0dB!

- unlike the common-emitter amplifier, no significant voltage division at the input, thanks to no r_o, and high-resistance bias network!

output Circuit:

define $R_D' = R_D \| r_o = 1k \| 40.18k = 0.9757\ k\Omega$

thus, $V_{out} = -g_m \cdot v_{gs} = -g_m (R_D' \| R_L)$

let $A_{v_2} = \frac{V_{out}}{v_{gs}} = -g_m (R_D' \| R_L)$ $\rightarrow 0.8164k$

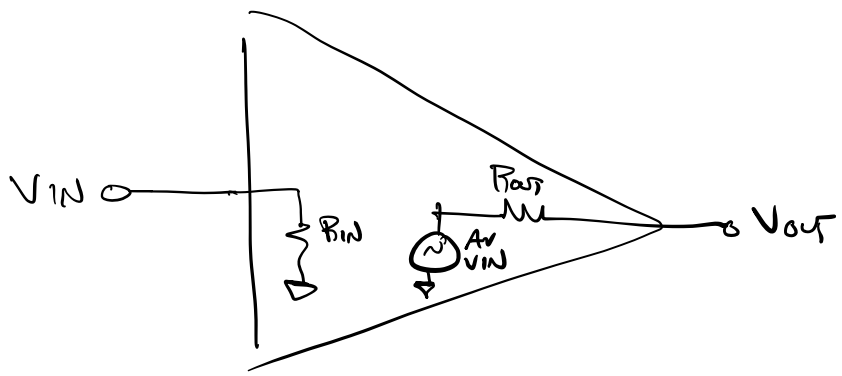
$= -14.11\ (0.9757 \| 5k)$

$A_{V_2} = -11.52$ or $21.23\ dB$, inverting

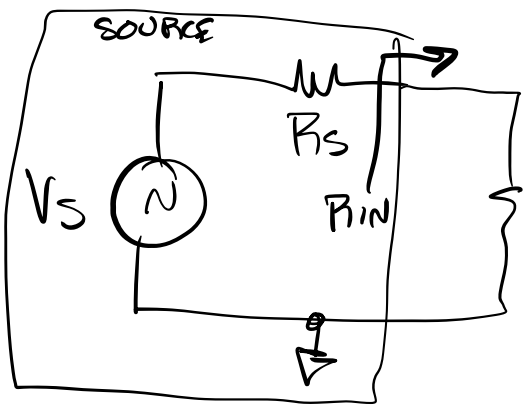
-- much lower gain than the BJT common-emitter examples!

Input and Output Resistances

remember:



-- looking into the input of the circuit from the perspective of Vs:

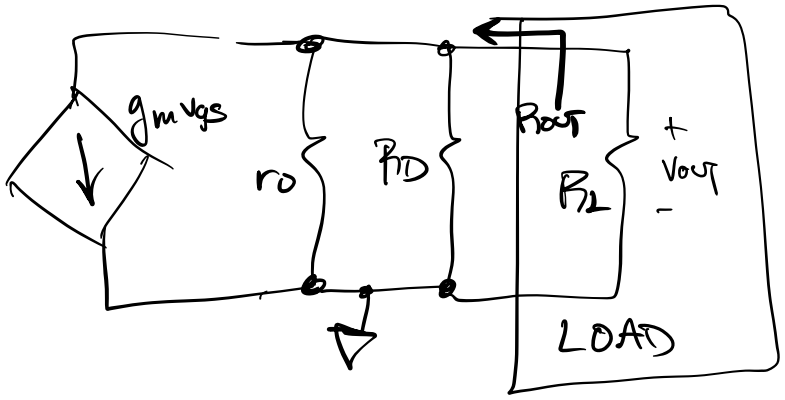


$R_{IN} = R_G$

$= 9\ M\Omega$

-- much higher value than common-emitter -- great!

-- looking into output from perspective of R_L:



$$R_{out} = R_D \| r_o = R_D' = 0.9757\ k\Omega$$

-- this is about what we had with CE; not great.

-- So, in conclusion, common-source FET voltage amplifier is analogous in <u>many</u> ways to common-emitter BJT voltage amplifier, but offers <u>much</u> higher input resistance at the expense of lower gain.