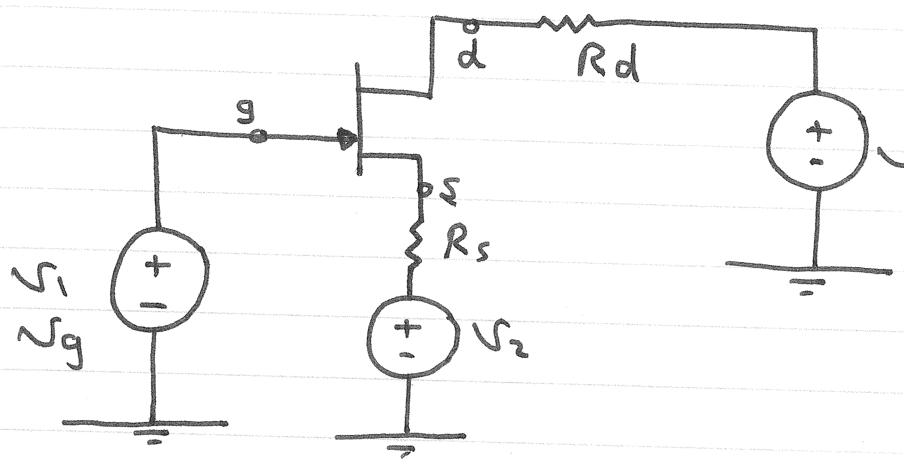
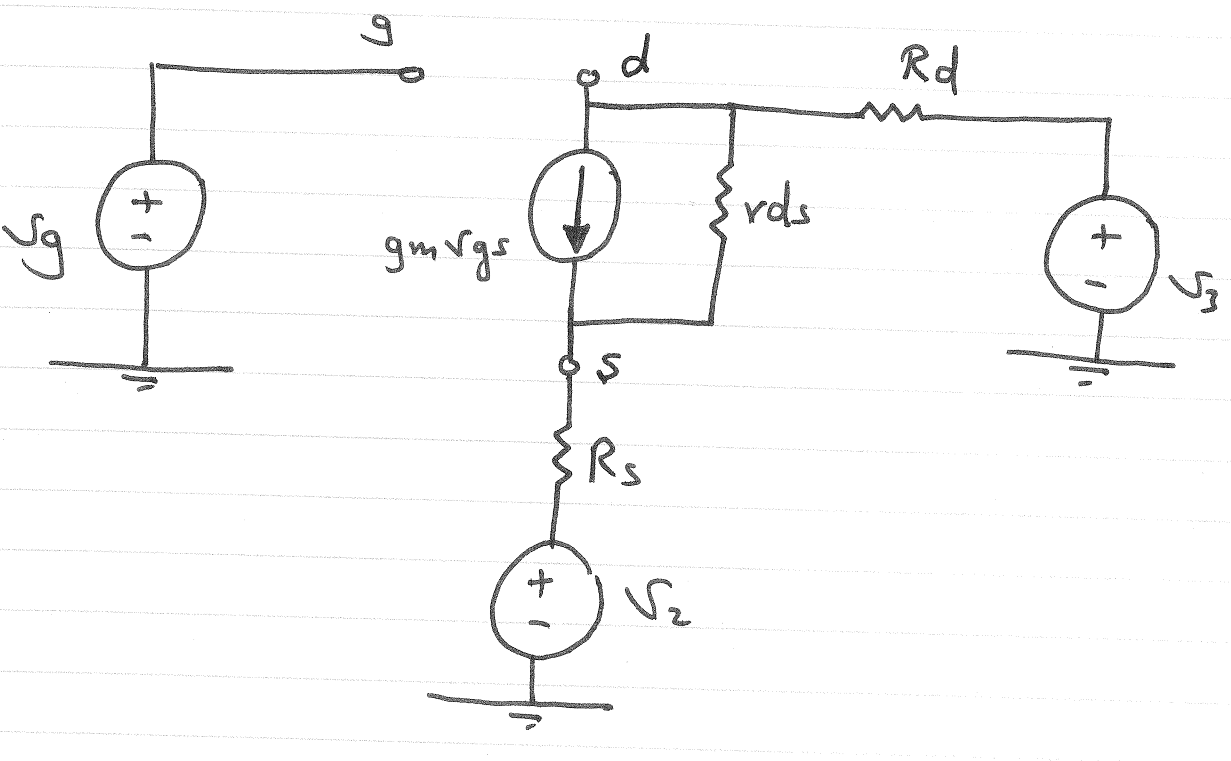
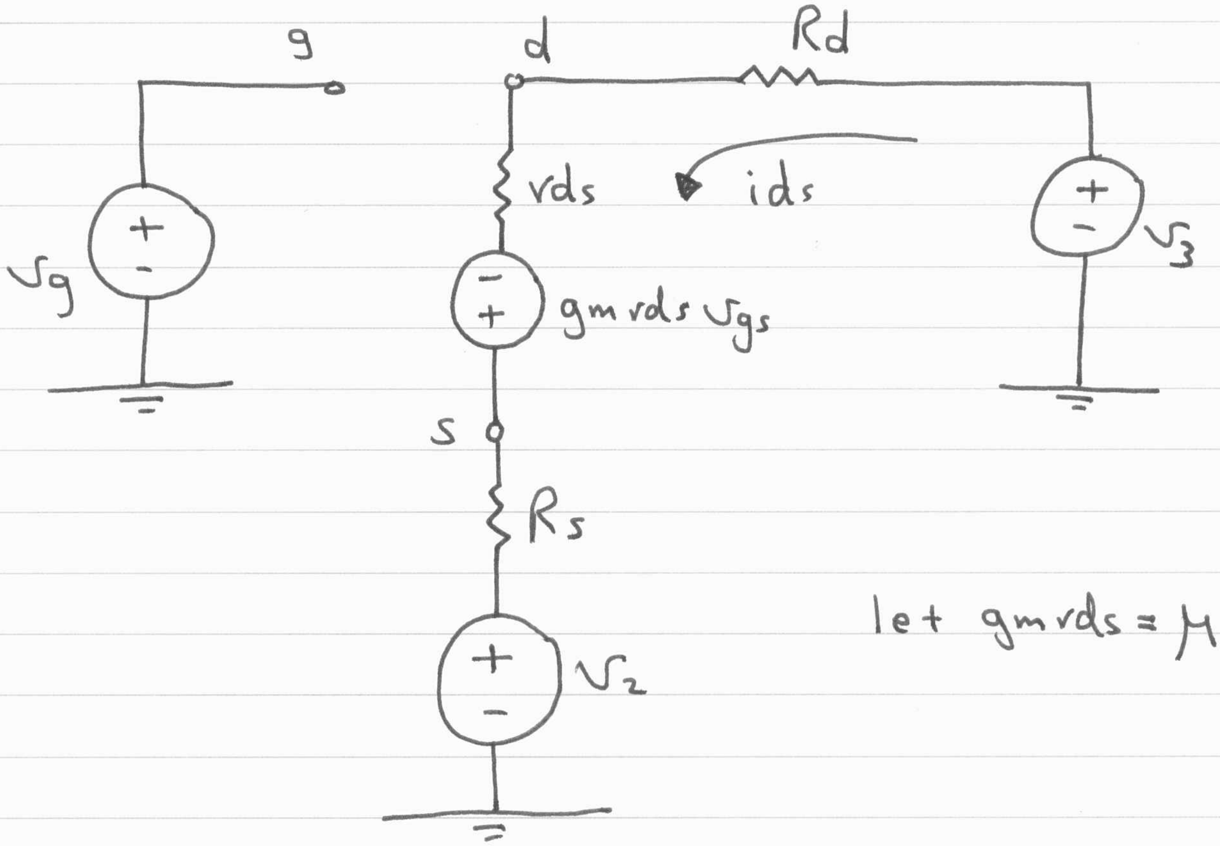
Impedance Reflection



ac small signal equivalent CKT :





let $g_m r_{ds} = \mu$

$$i_{ds} = \frac{v_3 + \mu v_{gs} - v_2}{R_d + R_s + r_{ds}}$$

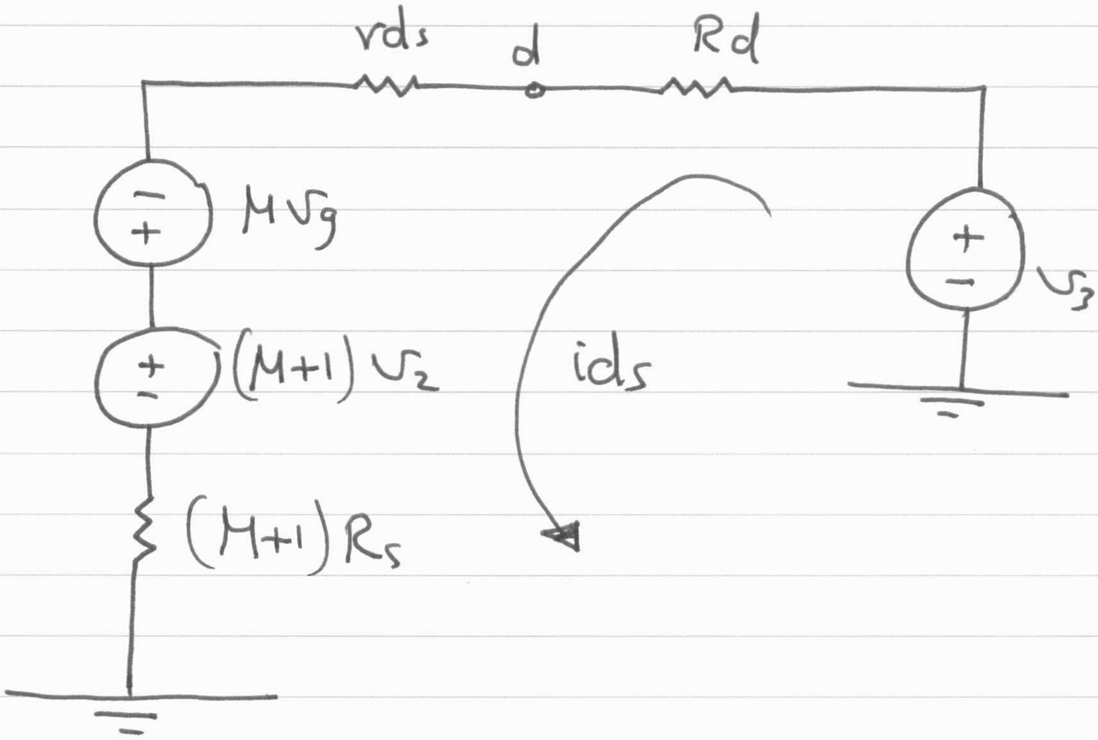
$$v_{gs} = v_g - v_s$$

$$v_s = R_s i_{ds} + v_2$$

$$\therefore i_{ds} = \frac{\mu v_g + v_3 - (\mu+1) v_2}{r_{ds} + R_d + (\mu+1) R_s}$$

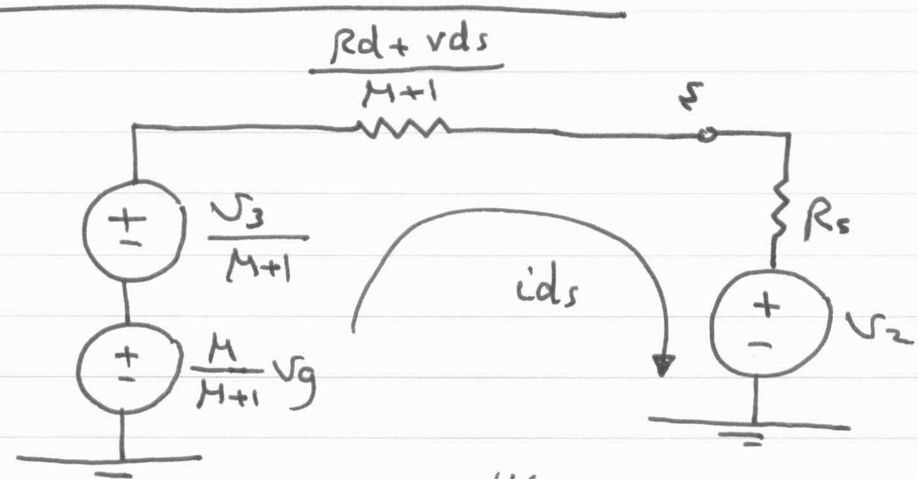
$$i_{ds} = \frac{\mu v_g + v_3 - (\mu+1) v_2}{r_{ds} + R_d + (\mu+1) R_s}$$

Drain equivalent CKT

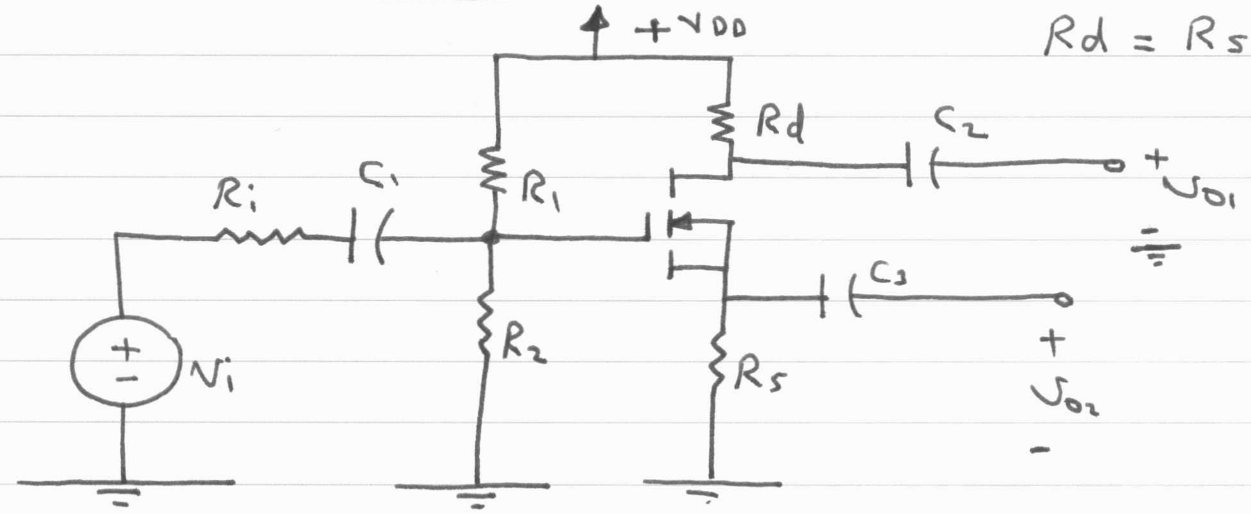


$$i_{ds} = \frac{\frac{\mu}{\mu+1} v_g + \frac{v_3}{\mu+1} - v_2}{R_s + \frac{R_d + r_{ds}}{\mu+1}}$$

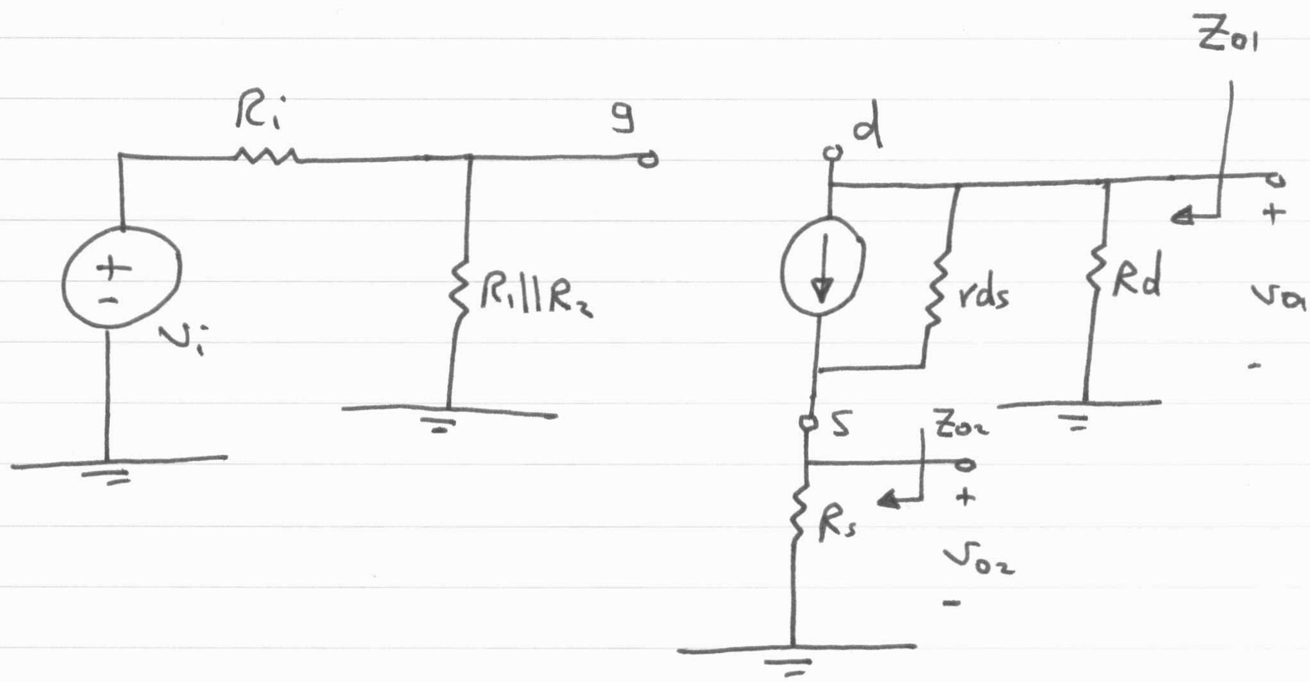
Source equivalent CKT



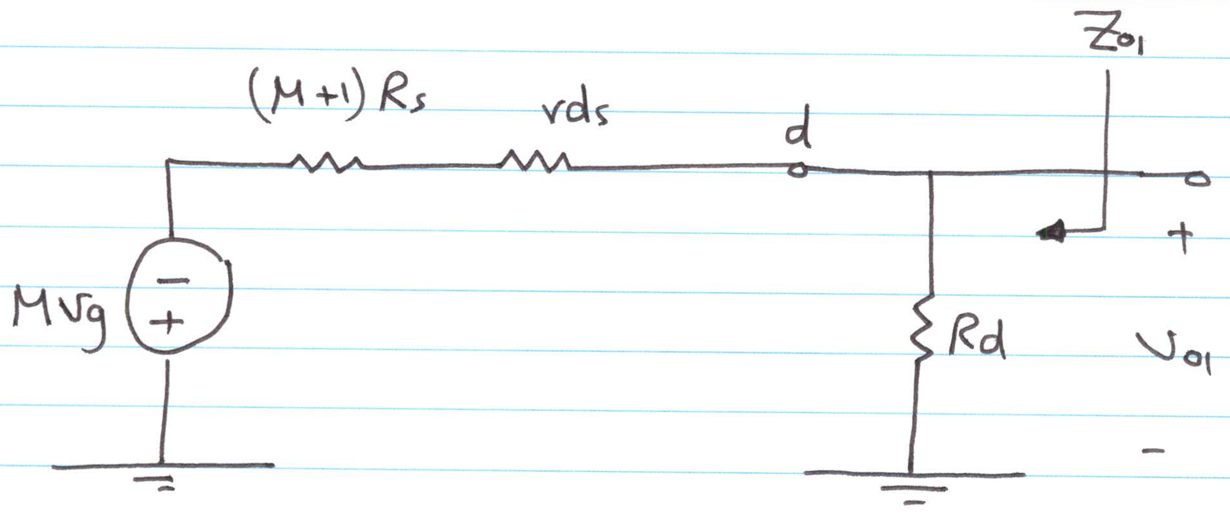
Phase splitting circuit



Ac Small signal equivalent CKT



a) To find v_{o1}, and Z_{o1}



$$v_{o1} = - \frac{R_d \; \mu v_g}{R_d + r_{ds} + (\mu+1)R_s}$$

$$v_g = \frac{R_1 \| R_2}{R_1 \| R_2 + R_i} v_i$$

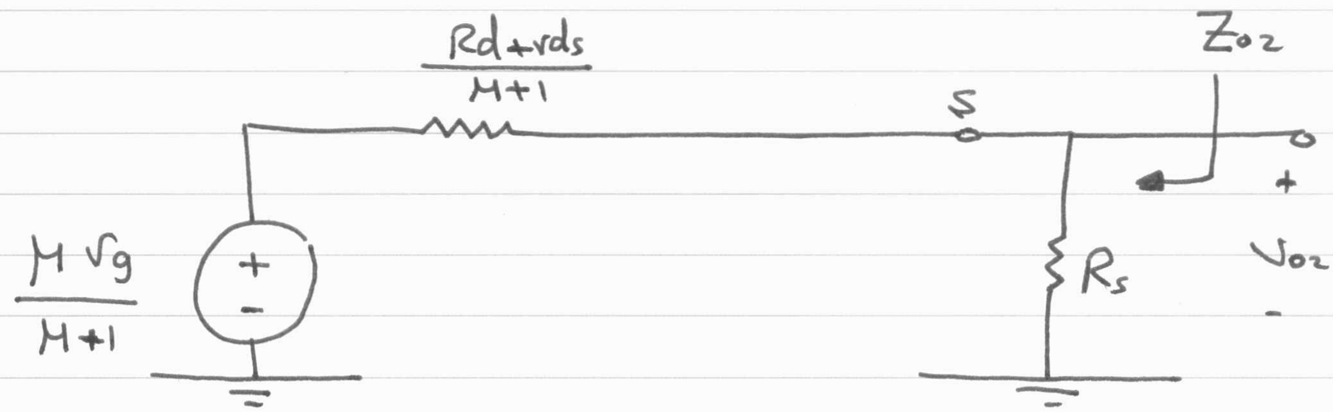
$$\therefore v_{o1} = - \frac{(R_1 \| R_2)}{R_1 \| R_2 + R_i} \cdot \frac{R_d \mu v_i}{R_d + r_{ds} + (\mu+1)R_s}$$

$$Z_{o1} = R_d \, \| \, \left(r_{ds} + (\mu+1)R_s \right)$$

if $r_{ds} = \infty$

$$\therefore Z_{o1} = R_d$$

b) To find v_{o2}, and Z_{o2}



$$v_{o2} = \frac{R_s\left(\frac{\mu}{\mu+1}\right)v_g}{R_s + \frac{R_d + r_{ds}}{\mu+1}}$$

$$v_g = \frac{R_1 \| R_2}{R_1 \| R_2 + R_i}\, v_i$$

$$v_{o2} = \frac{R_1 \| R_2}{R_1 \| R_2 + R_i} \; \frac{R_s\left(\frac{\mu}{\mu+1}\right)v_i}{R_s + \frac{R_d + r_{ds}}{\mu+1}}$$

$$v_{o2} = \frac{R_1 \| R_2}{R_1 \| R_2 + R_i} \; \frac{R_s\, \mu v_i}{(R_d + r_{ds}) + (\mu+1)R_s}$$

$$\therefore |v_{o2}| = |v_{o1}|$$

if $R_s = R_d$

$$Z_{o2} = R_s \,\Big\|\, \frac{R_d + r_{ds}}{\mu+1}$$

$$Z_{o2} = R_s \parallel \frac{R_d + r_{ds}}{\mu + 1}$$

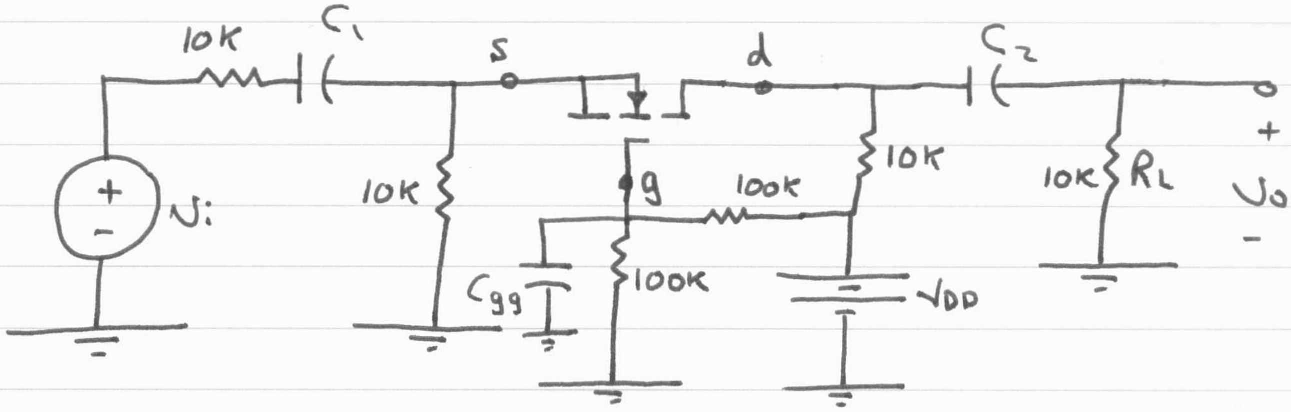
if $r_{ds} = \infty$

$$\frac{R_d + r_{ds}}{\mu + 1} = \frac{R_d + r_{ds}}{g_m r_{ds} + 1}$$

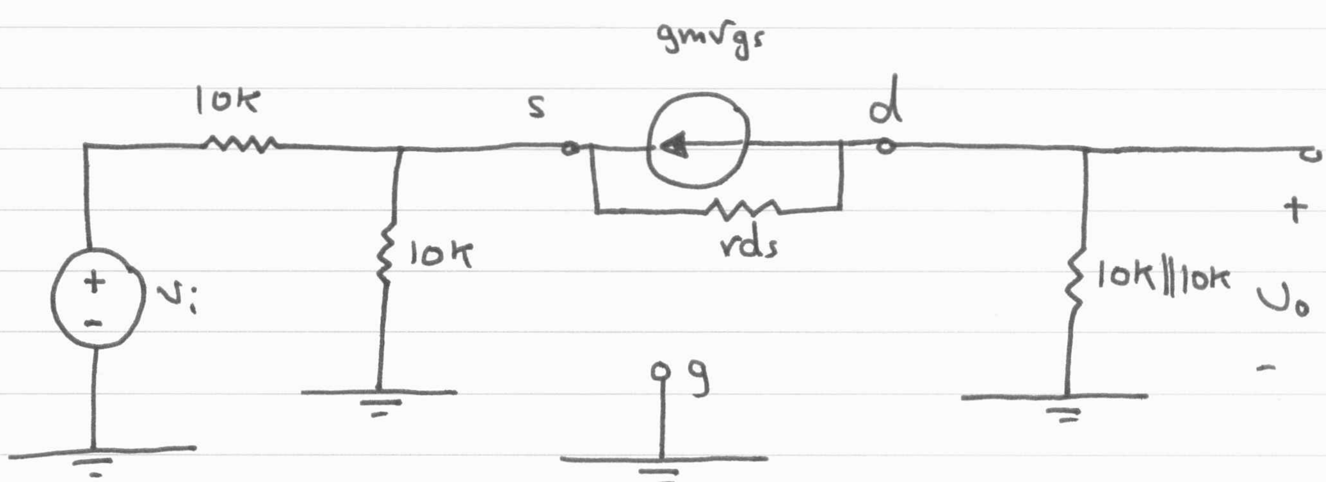
$$\lim_{r_{ds} \to \infty} \frac{R_d + r_{ds}}{g_m r_{ds} + 1} = \frac{1}{g_m}$$

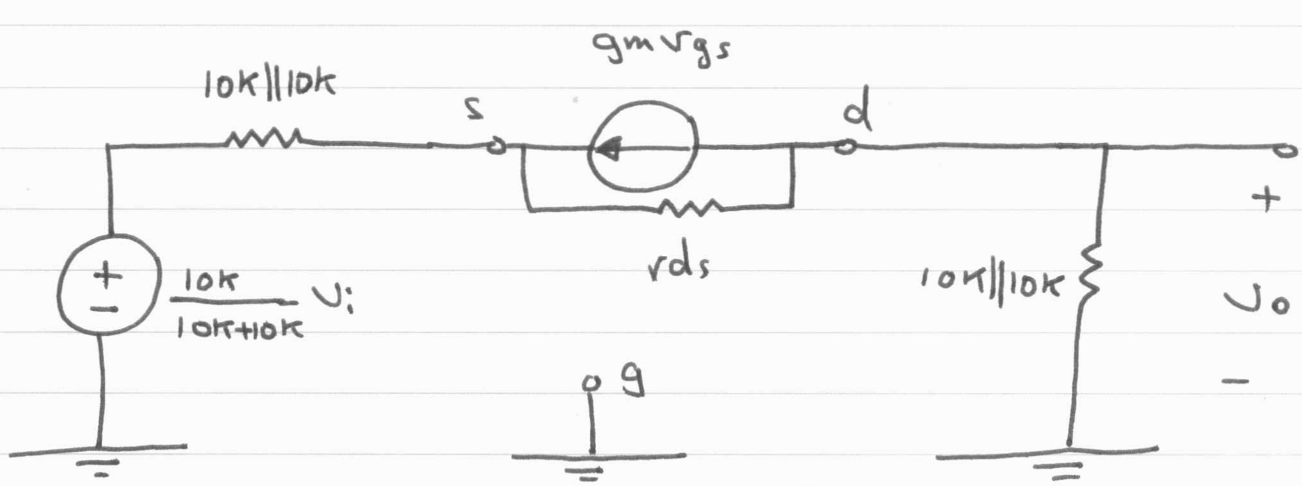
$\therefore$ if $r_{ds} = \infty$; $Z_{o2} = R_s \parallel \frac{1}{g_m}$

Common Gate Amplifier

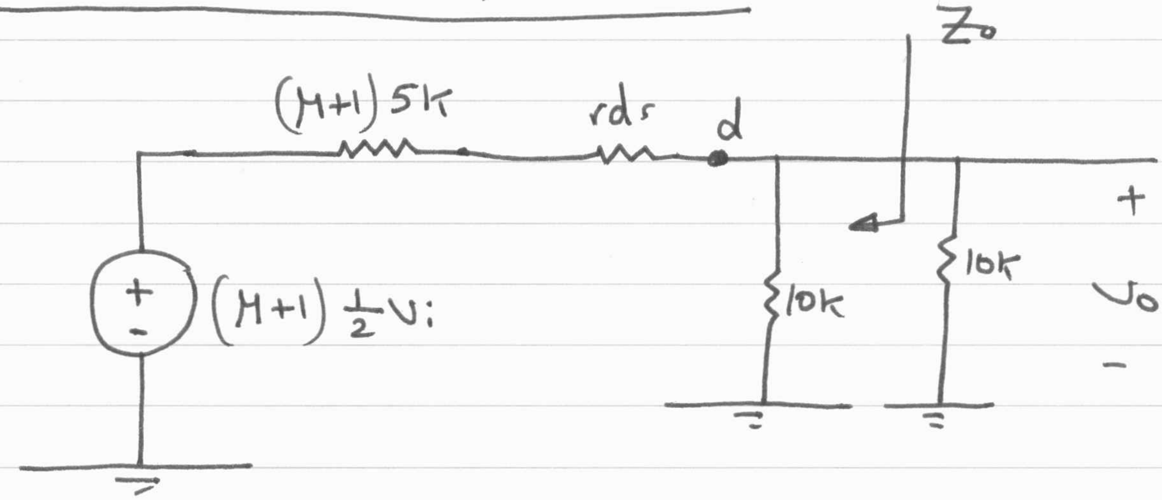


Ac Small Signal Equivalent Circuit





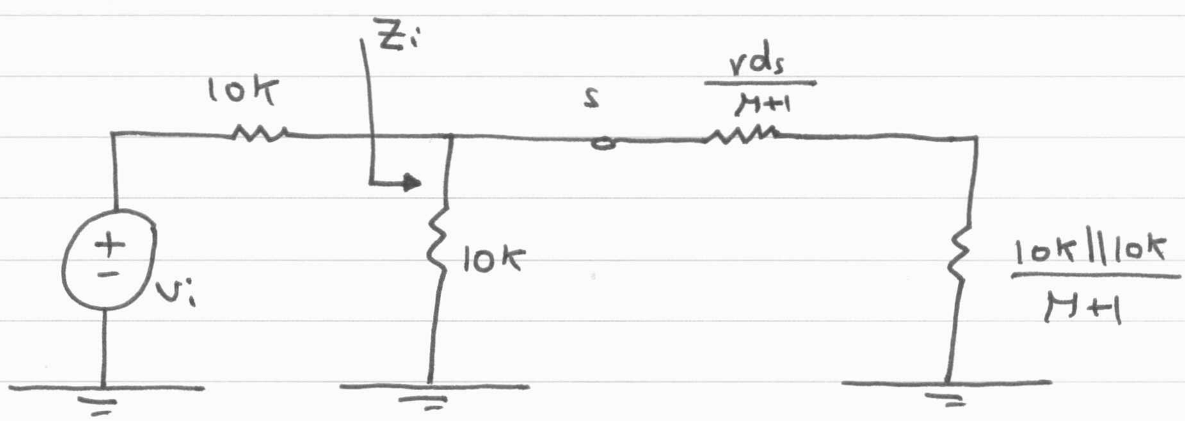
To Find v_o , and Z_o



$$v_o = \frac{(10k \| 10k)(\mu+1)\frac{1}{2}v_i}{10k \| 10k + r_{ds} + (\mu+1)5k}$$

$$Z_o = 10k \,\|\, \left[r_{ds} + (\mu+1)5k\right]$$

To find Z_i ⟶ Source equivalent CKT

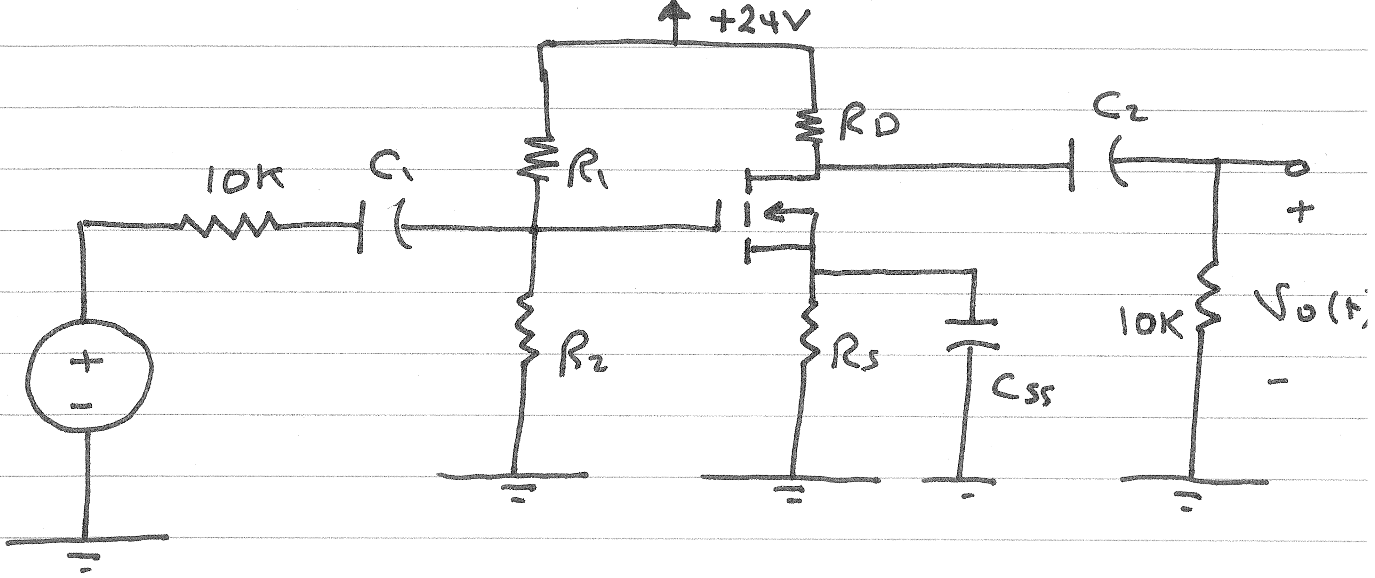


$$Z_i = 10k \,\Big\|\, \frac{r_{ds} + 10k \| 10k}{\mu+1}$$

Common Source Amplifier : Design

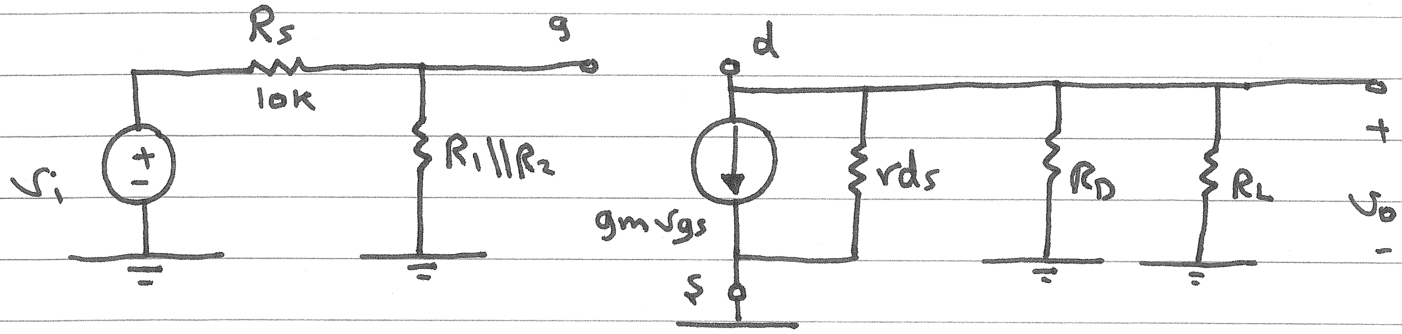
Design the MOSFET Amplifier shown to have a gain of 10 and $Z_i = 1M\Omega$

Assume $V_{GS} = 3V$, $V_{DS} = 4V$, $I_{DS} = 5mA$, $r_{ds} = 20K\Omega$ and $K_n = 2mA/V^2$.



Solution

ac small Signal equivalent circuit



$$v_o = -g_m v_{gs} (r_{ds} \| R_D \| R_L)$$

$$v_{gs} = v_g - v_s = v_g = \frac{R_1 \| R_2}{R_1 \| R_2 + R_s} v_i$$

$$v_{gs} = \frac{Z_i}{Z_i + 10K} v_i = \frac{1M}{1M + 10K} v_i \approx v_i$$

$$\therefore |A_v| = g_m (r_{ds} \| 10K \| R_D)$$

$$|A_v| = g_m (6.67K \| R_D)$$

$$g_m = 2\sqrt{K_n I_{DS}} = 6.23\ m\mho$$

$$\therefore \text{For } |A_v| = 10 \longrightarrow R_D = 2.1K$$

From DC Analysis

$V_{DD} = (R_D + R_S) I_{DS} + V_{DS}$

$\therefore \quad R_D + R_S = 4K$

$\therefore \quad R_S = 1.9K$

$\therefore \quad V_S = 9.5V$

$V_G = V_{GS} + V_S$

$V_G = 3 + 9.5 = 12.5V$

$$V_G = \frac{R_2}{R_1 + R_2} V_{DD} = 12.5V$$

$$Z_i = \frac{R_1 R_2}{R_1 + R_2} = 1M\Omega$$

Solving for R_1 and R_2

$R_1 = 1.92 M\Omega$

$R_2 = 2.1 M\Omega$