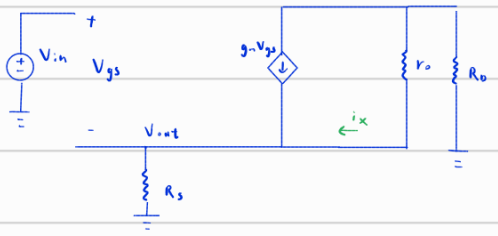
1.1 111511076 陳彥宇

(a)



$V_{in} = V_{out} + V_{gs}$

$\frac{V_{out}}{R_S} = g_m V_{gs} + i_x$

$V_{out} + i_x r_o = -R_D(i_x + g_m V_{gs})$

$(r_o + R_D) i_x = -V_{out} - R_D g_m (V_{in} - V_{out})$

$i_x = \frac{(R_D g_m - 1) V_{out} - R_D g_m V_{in}}{R_D + r_o}$

$\frac{V_{out}}{R_S} = g_m (V_{in} - V_{out}) + i_x$

$= g_m (V_{in} - V_{out}) + \frac{(R_D g_m - 1) V_{out} - R_D g_m V_{in}}{R_D + r_o}$

$V_{out} = g_m R_S (V_{in} - V_{out}) + R_S \frac{(R_D g_m - 1) V_{out} - R_D g_m V_{in}}{R_D + r_o}$

$(R_D + r_o) V_{out} = (R_D + r_o) g_m R_S (V_{in} - V_{out}) + R_S[(R_D g_m - 1) V_{out} - R_D g_m V_{in}]$

$(R_D + r_o) V_{out} = (R_D g_m R_S + r_o g_m R_S) - V_{out} + (R_D g_m R_S + r_o g_m R_S) V_{in}$

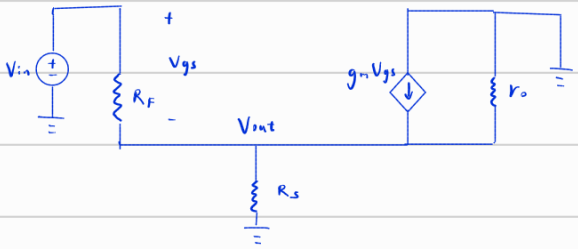
$+ (R_S R_D g_m - R_S) V_{out} - R_S R_D g_m V_{in}$

$(R_D + r_o + \cancel{R_D g_m R_S} + r_o g_m R_S - \cancel{R_S R_D g_m} + R_S) V_{out} = (\cancel{R_D g_m R_S} + r_o g_m R_S - \cancel{R_S R_D g_m}) V_{in}$

$V_{out} = \frac{g_m r_o R_S}{R_D + R_S + r_o + r_o g_m R_S} V_{in}$

$A_V = \frac{g_m r_o R_S}{R_D + R_S + r_o + r_o g_m R_S}$ V/V #

(b)



$V_{gs} = V_{in} - V_{out}$

$\frac{V_{in} - V_{out}}{R_F} + g_m V_{gs} + \frac{0 - V_{out}}{r_o} = \frac{V_{out}}{R_S}$

$(\frac{1}{R_F} + \frac{1}{r_o} + \frac{1}{R_S}) V_{out} = g_m (V_{in} - V_{out}) + \frac{1}{R_F} V_{in}$

$(\frac{1}{R_F} + \frac{1}{r_o} + \frac{1}{R_S} + g_m) V_{out} = (g_m + \frac{1}{R_F}) V_{in}$

$(r_o R_S + R_F R_S + R_F r_o + g_m R_F R_S r_o) V_{out} = (g_m R_F R_S r_o + R_S r_o) V_{in}$

$V_{out} = \frac{g_m R_F R_S r_o + R_S r_o}{r_o R_S + R_F R_S + R_F r_o + g_m R_F R_S r_o} V_{in}$

$A_V = \frac{g_m R_F R_S r_o + R_S r_o}{r_o R_S + R_F R_S + R_F r_o + g_m R_F R_S r_o}$ (V/V) #

1.2

$V_{th_n} = 0.7$ $\quad C_{ox} = 3.9 \frac{\varepsilon_0}{t_{ox}} = 3.9 \frac{8.854 \times 10^{-12}\ m}{9 \times 10^{-9}\ m} = 3.83673 \times 10^{-3}\ F/m^2$

$= 3.83673 \times 10^{-7}\ F/cm^2$

(a) Let $V_{out} = x$, then $V_{in} = x + 1$

$V_{gs1} = V_{in} - V_{out} = 1$

$V_{gs2} = V_b = V_{gs1} + 0.5 = 1.5$

$k_n' = \mu_n C_{ox} = 350 \times 3.83673 \times 10^{-7} = 0.13286\ mA/V^2$

$k = \mu C_{ox} \frac{W}{L}$

$I_{D1} = \frac{1}{2} k' \frac{W}{L} (V_{gs1} - 0.7)^2$

$0.5\ m = \frac{1}{2} \cdot 0.13286\ m \left(\frac{W}{L}\right)_1 (1 - 0.7)^2$

$\left(\frac{W}{L}\right)_1 = 83.630$ #

$I_{D2} = 0.5\ m = \frac{1}{2} \cdot 0.13286\ m \left(\frac{W}{L}\right)_2 (0.8)^2$

$\left(\frac{W}{L}\right)_2 = 11.760$ #

(b)

$V_t = V_{t0} + \gamma \left[\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f} \right]$

$V_{in} = 2.5\ V$

$V_{out} = 1.5\ V$

$V_b = 1.5\ V$

$V_{SB1} = 1.5\ V$ $\quad V_{t1} = 0.7 + 0.45 \left[\sqrt{0.9 + 1.5} - \sqrt{0.9} \right] = 0.97023$

$V_{SB2} = 0\ V$ $\quad M_2$ has no body effect, $V_{t2} = 0.7\ V$

$I_{D1} = \frac{1}{2} k' \frac{W}{L} (V_{gs1} - 0.7)^2$

$0.5\ m = \frac{1}{2} \cdot 0.13286\ m \left(\frac{W}{L}\right)_1 (1 - 0.97023)^2$

$\left(\frac{W}{L}\right)_1 = 8492.745$ #

$I_{D2} = 0.5\ m = \frac{1}{2} \cdot 0.13286\ m \left(\frac{W}{L}\right)_2 (0.8)^2$

$\left(\frac{W}{L}\right)_2 = 11.760$ #

(c) $V_{DS2} \geq V_b - V_{t2}$ $\quad V_{SB1} \geq 0.8$

$\Rightarrow V_{out} \geq V_b - V_{t2}$ $\quad V_{t1} = 0.7 + 0.45 \left[\sqrt{0.9 + 0.8} - \sqrt{0.9} \right]$

$V_{out} \geq 0.8$ $\quad = 0.85982$

$$0.5m = \frac{1}{2} \cdot 0.13286m \cdot 8492.745 \cdot (V_{in} - 0.8 - 0.85982)$$

$$V_{in} = 1.68959$$

$$= 1.690\ V \ \#$$

1.3

$$V_{DD} = 3V \qquad R_D = 2k$$

(a) For $V_{out} = 1V$, $I_D = 1mA$

$$k_n' = \mu_n C_{ox} = 350 \times 3.83693 \times 10^{-7} = 0.13286\ mA/V^2$$

$$I_m = \frac{1}{2} k' \left(\frac{W}{L}\right) V_{ov}^2$$

$$= \frac{1}{2} \cdot 0.13286m \cdot 120 \cdot V_{ov}^2$$

$$V_{ov} = 0.3592\ V \qquad V_{th\,n} = 0.7\ V$$

$$V_{in} = 1.059\ V \ \#$$

For $V_{out} = 2V$, $I_D = 0.5mA$

$$0.5m = \frac{1}{2} k' \left(\frac{W}{L}\right) V_{ov}^2$$

$$= \frac{1}{2} \cdot 0.13286m \cdot 120 \cdot V_{ov}^2$$

$$V_{ov} = 0.2509\ V$$

$$V_{in} = 0.925\ V \ \#$$

(b) $k = 15.9932\ mA/V^2$ $\qquad I_{D(b)} = I_m \qquad g_{m(b)}$

$g_m = k V_{ov}$ $\qquad I_{D(c)} = I_m \qquad g_{m(c)}$

$= \frac{2I_D}{V_{ov}}$ $\qquad = I_D \cdot (1 + \lambda_0 V_{DS})$

$= \sqrt{2kI}$

For $V_{out} = 1V$, $I_D = 1mA$, $g_m = 5.697\ mA/V$ #

For $V_{out} = 2V$, $I_D = 0.5mA$, $g_m = 3.993\ mA/V$ #

(c) $\lambda = 0.1$

$$r_o = \frac{1}{\lambda I_D}$$

$$A_V = -g_m (R_D \| r_o)$$

For $V_{out} = 1V$, $r_o = \frac{1}{0.1 \cdot 1m} = 10k$ (λ accounted for) $\qquad 10k \| 2k = 1.6667k$ (用 (b) 的 g_m)

$g_m = \sqrt{2kI(1+\lambda V_{DS})} = 5.92242\ m$ $\qquad A_V = -9.412\ V/V$ #

For $V_{out} = 2V$, $r_o = \frac{1}{0.1 \cdot 0.5m} = 20k$ $\qquad 20k \| 2k = 1.81818k$ (用 (b) 的 g_m)

$g_m = 4.37399\ m$ (λ accounted for) $\qquad A_V = -7.260\ V/V$ #