For the inductively-loaded CS stage of Fig. 4.2, determine $\boldsymbol{V_{out}/V_{in}}$ and find the voltage gain at the resonance frequency, $\boldsymbol{\omega_0 = 1/\sqrt{L_1(C_1 + C_F)}}$, if $\boldsymbol{|jC_1\omega_0| \ll g_m}$.

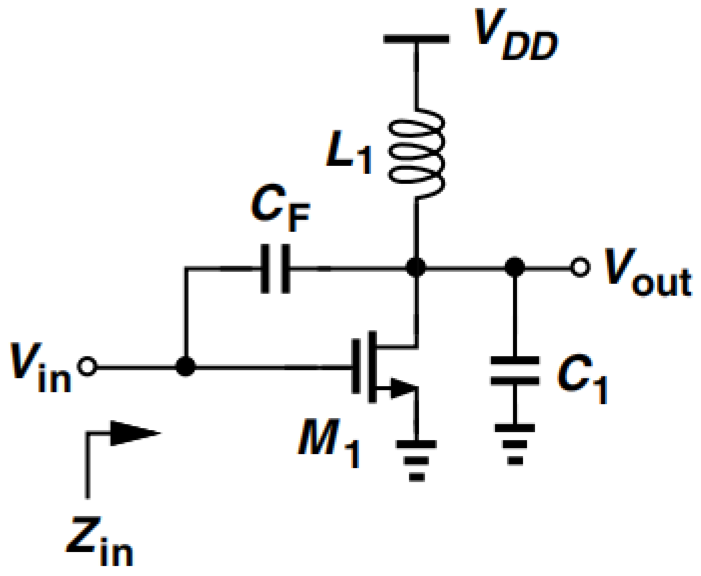
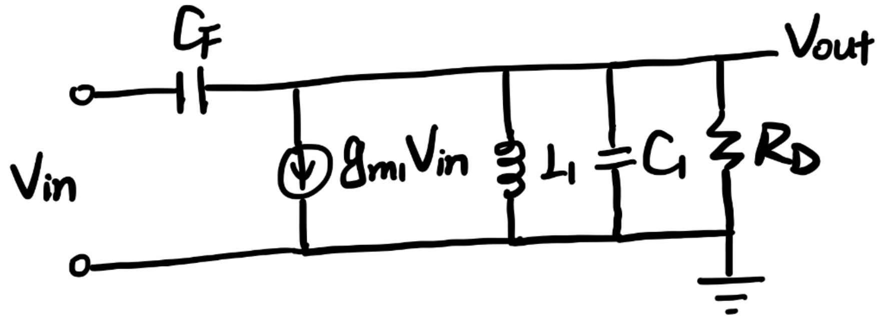


Fig. 4.2



$$\frac{V_{in} - V_{out}}{\frac{1}{C_F s}} = g_{m1}V_{in} + \frac{V_{out}}{L_1 s} + \frac{V_{out}}{\frac{1}{C_1 s}} + \frac{V_{out}}{R_P}$$

$$\frac{V_{out}}{V_{in}} = \frac{C_F s - g_{m1}}{(C_1 + C_F)s + \frac{1}{L_1 s} + \frac{1}{R_P}}$$

(R_P is the model of loss on L_1)

At ω_0:

$$\frac{V_{out}}{V_{in}}(\omega_0) = \frac{j\omega_0 C_F - g_{m1}}{1/R_P} \approx -\frac{g_{m1}}{1/R_P}$$

For the complementary stage shown in Fig. 4.3, determine the closed-loop gain and noise figure if channel-length modulation is not neglected. Assume matching at the input.

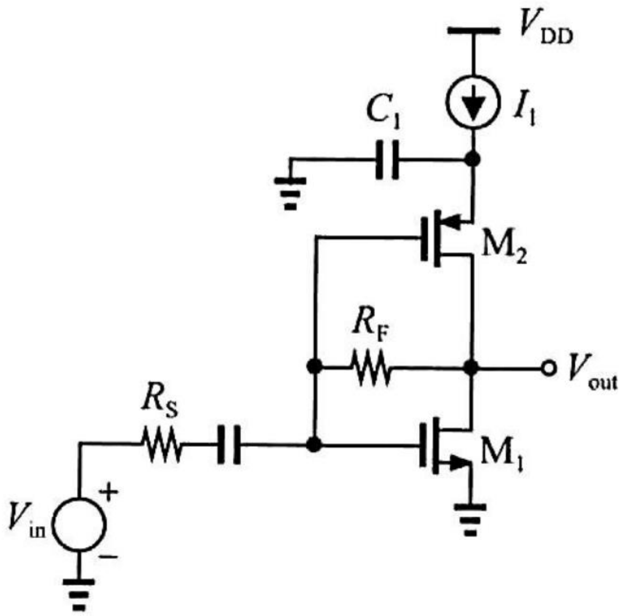
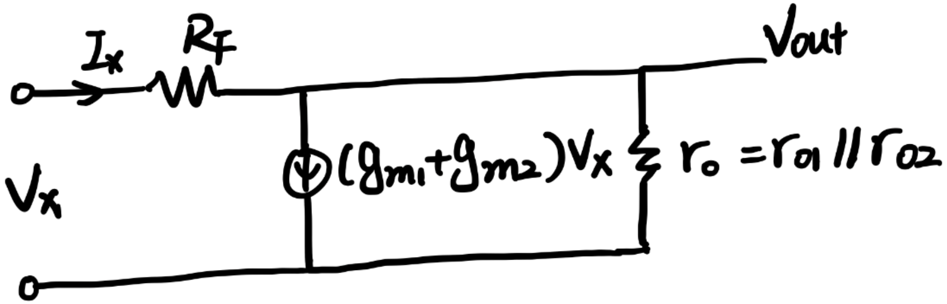


Fig. 4.3



$$I_x = (g_{m1} + g_{m2})V_x + \frac{V_x - I_x R_F}{r_o}$$

$$\Rightarrow \frac{V_x}{I_x} = R_{in} = \frac{r_o + R_F}{(g_{m1} + g_{m2})r_o + 1} = R_s$$

$$\frac{V_{out}}{V_x} = 1 - \frac{R_F}{R_s}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{1}{2}(1 - \frac{R_F}{R_s})$$

Noise of R_F:

$$\overline{V_{n,RF}^2} = 4kTR_F \left(\frac{1 - (g_{m1} + g_{m2})R_F}{1 - (g_{m1} + g_{m2})R_F - \frac{R_F + R_s}{r_o}} \right)$$

Noise of M1, M2:

$$\overline{V_{n,M1\&M2}^2} = 4kT\gamma(g_{m1} + g_{m2}) \cdot \left(\frac{R_F + R_s}{\frac{R_F + R_s}{r_o} + R_F(g_{m1} + g_{m2}) + 1} \right)^2$$

$$\Rightarrow NF = 1 + \frac{\overline{V_{n,RF}^2} + \overline{V_{n,M1\&M2}^2}}{\left[\frac{1}{2}\left(1 - \frac{R_F}{R_s}\right)\right]^2} \cdot \frac{1}{4kTR_s}$$

A circuit exhibits a noise figure of 3 dB. What percentage of the output noise power is due to the source resistance, R_S? Repeat the problem for NF=1 dB.

(1)

$$NF = 1 + \frac{\overline{V_{n,out}^2}}{A_v^2} \cdot \frac{1}{4kTR_s}, where\ \overline{V_{n,out}^2}\ is\ not\ due\ to\ R_s$$

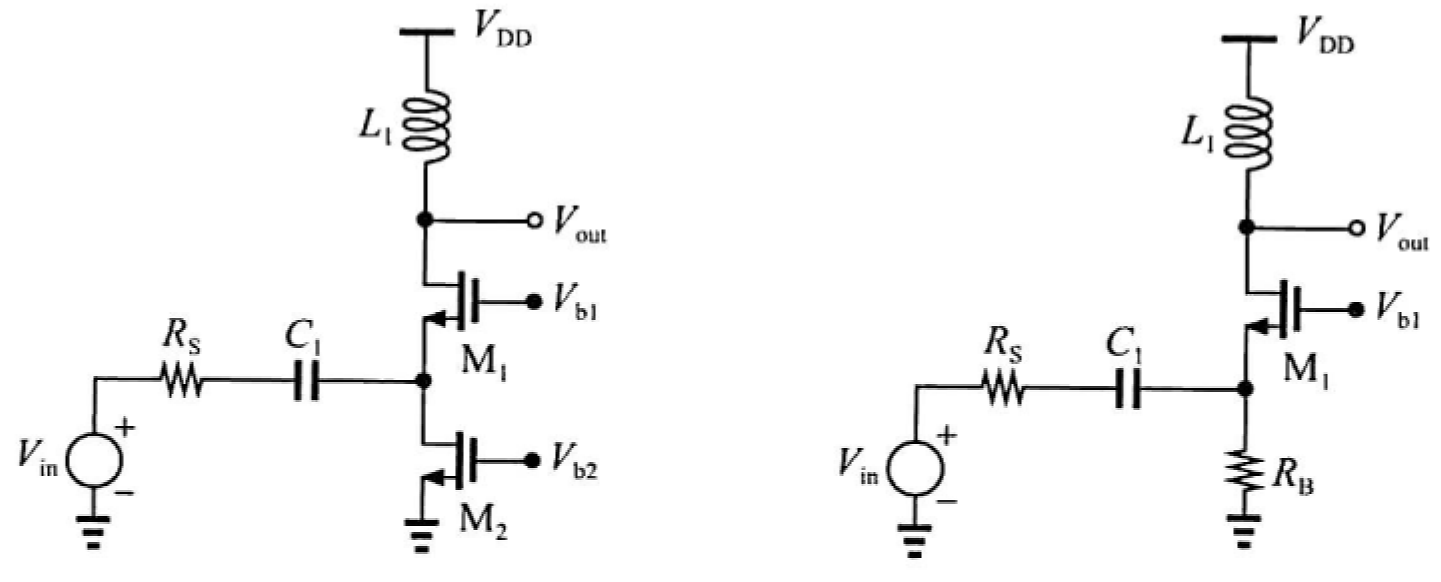
$$\Rightarrow \mathrm{NF} = 1 + \frac{\overline{V_{n,in}^2}}{4kTR_s} = 3dB \Rightarrow \overline{V_{n,in}^2} = 4kTR_s \Rightarrow 50\%$$

(2)

$$NF = 1dB = 1.26$$

$$\Rightarrow \overline{V_{n,in}^2} = 0.26 \times 4kTR_s \Rightarrow 1 - \frac{0.26}{1.26} = 79.37\%$$

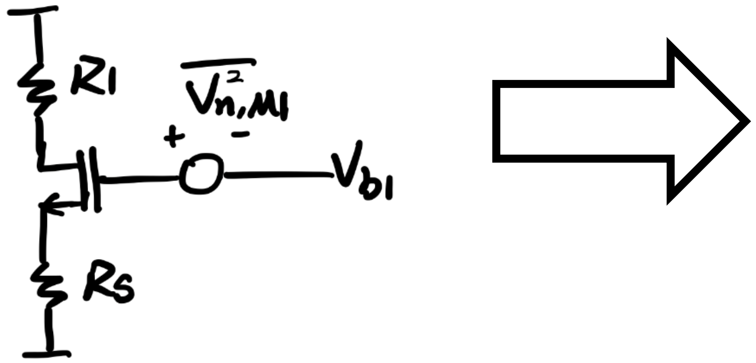
Determine the noise figure of the CG circuits shown in Fig. 4.4.



(a) (b)

Fig. 4.4

(a)

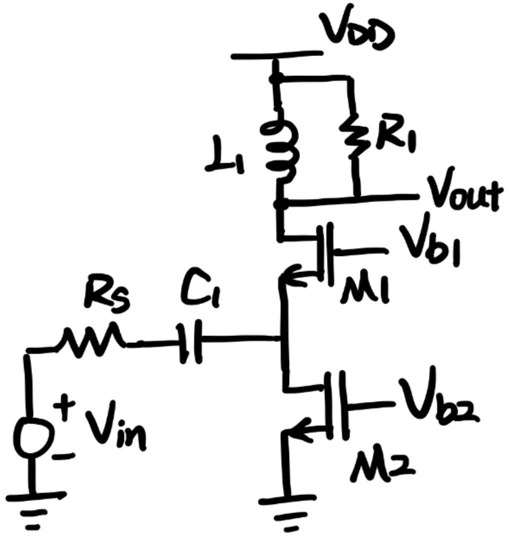


$$\overline{V_{n,out\ M1}^2} = \frac{4kT\gamma}{g_m}\left(\frac{R_1}{R_s + \frac{1}{g_{m1}}}\right)^2 = kT\gamma\frac{R_1^2}{R_s}$$

$$\overline{V_{n,out\ M2}^2} = 4kT\gamma g_{m2} R_1^2$$

$$\overline{V_{n,out\ R1}^2} = 4kTR_1$$

if input is matched, $\frac{V_{out}}{V_{in}} = \frac{R_1}{2R_s}$



$$NF = 1 + \frac{\gamma}{g_{m1}R_s} + 4\frac{R_s}{R_1} + 4R_s \cdot g_{m2}$$

(b)

If M2 is replaced by R_B

$$\overline{V_{n,out\ R_B}^2} = \frac{4kT}{R_B}R_1^2$$

$$NF = 1 + \frac{\gamma}{g_{m1}R_s} + 4\frac{R_s}{R_1} + 4\frac{R_s}{R_B}$$