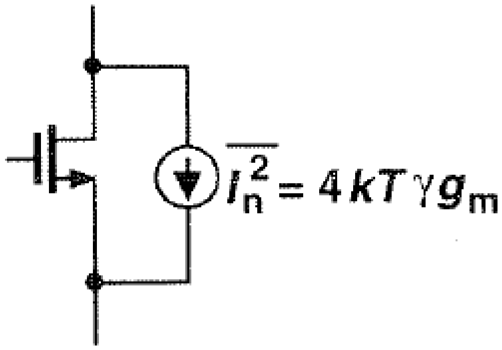
Razavi



Thermal noise represented as a current in parallel on the output

$$\overline{I_n^2} = 4kT\gamma g_m$$

Converted to voltage at the input with γ=2/3. NB! For small line widths (i.e. L for example equal to 0.25μm) γ can be up to 2-3.

$$\overline{V_n^2} = \overline{I_n^2} r_O^2 = 4kT\left(\frac{2}{3} g_m\right) r_O^2$$

Flicker represented as a voltage in series on the gate.

$$\overline{V_n^2} = \frac{K}{C_{OX}WL} \cdot \frac{1}{f}$$

Common-Source

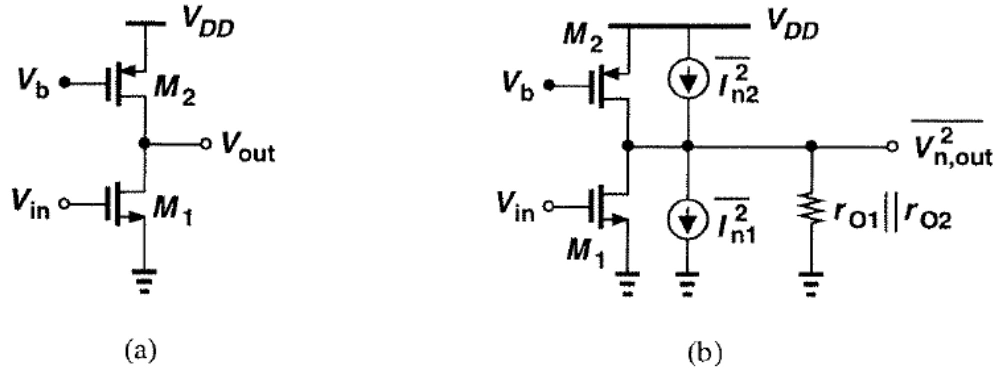


Figure 7.35

Vn noise on the gate of M1.

$$\overline{V_n^2} = 4kT\left(\frac{2}{3}g_{m1} + \frac{2}{3}g_{m2}\right)\frac{1}{g_{m1}^2} = 4kT\left(\frac{2}{3g_{m1}} + \frac{2}{3}\frac{g_{m2}}{g_{m1}^2}\right)$$

Noise on the output (with capacitive load C_L) integrated over all frequencies:

$$\overline{V^2_{n,out,tot}} = \int_0^\infty 4kT\left(\frac{2}{3}g_{m1} + \frac{2}{3}g_{m2}\right)(r_{O1}\parallel r_{O2})^2 \frac{df}{1+(r_{O1}\parallel r_{O2})^2 C_L^2 (2\pi f)^2} = \frac{2}{3}(g_{m1}+g_{m2})(r_{O1}\parallel r_{O2})\frac{kT}{C_L}$$

SNR for input sine with amplitude Vm

$$SNR_{OUT} = \left[\frac{g_{m1}(r_{O1}\parallel r_{O2})V_m}{\sqrt{2}}\right]^2 \cdot \frac{1}{(2/3)(g_{m1}+g_{m2})(r_{O1}\parallel r_{O2})(kT/C_L)} = \frac{3C_L}{4kT}\cdot\frac{g_{m1}^2(r_{O1}\parallel r_{O2})}{g_{m1}+g_{m2}}\cdot V_m^2$$

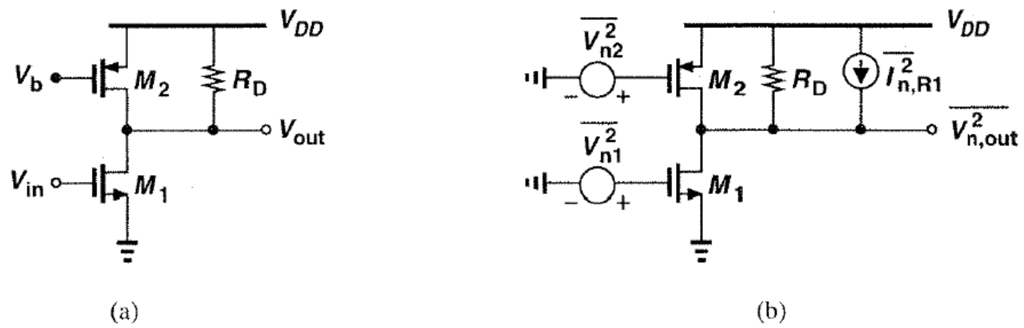


Figure 7.36

$$\overline{V^2_{n,in}} = 4kT\frac{2}{3}\left(\frac{g_{m2}}{g_{m1}^2} + \frac{1}{g_{m1}}\right) + \frac{1}{C_{ox}}\left[\frac{K_P g_{m2}^2}{(WL)_2 g_{m1}^2} + \frac{K_N}{(WL)_1}\right]\frac{1}{f} + \frac{4kT}{g_{m1}^2 R_D}$$

First brackets: Thermal noise, second brackets: flicker noise, last term: RD

Common-Gate

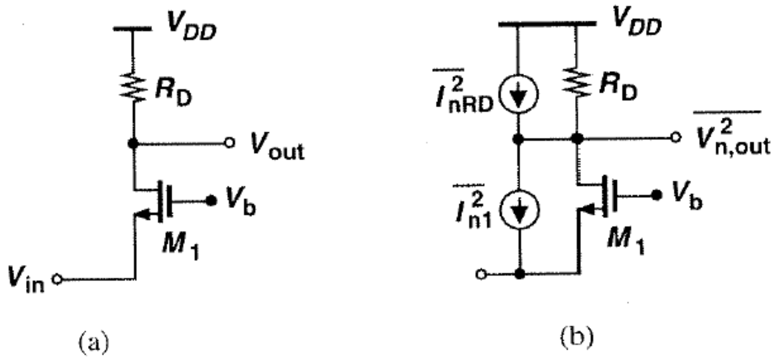


Figure 7.37 (a) CG stage, (b) circuit including noise sources.

$$\overline{V^2_{n,in}} = \frac{4kT(2g_m/3 + 1/R_D)}{(g_m + g_{mb})^2}$$

$$\overline{I^2_{n,in}} = \frac{4kT}{R_D}$$

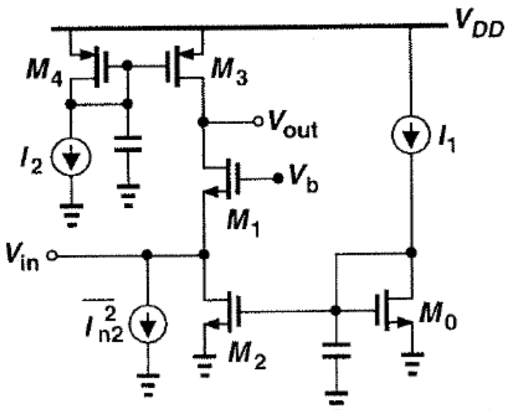


Figure 7.40

Thermal noise:

$$\overline{V^2_{n,in}} = 4kT\frac{2}{3}\frac{(g_{m1} + g_{m3})}{(g_{m1} + g_{mb1})^2}$$

$$\overline{I^2_{n.in}} = 4kT\frac{2}{3}(g_{m2} + g_{m3})$$

Flicker noise:

$$\overline{V^2_{n.in}} = \frac{1}{C_{ox}f}\left[\frac{g^2_{m1}K_N}{(WL)_1} + \frac{g^2_{m3}K_P}{(WL)_3}\right]\frac{1}{(g_{m1} + g_{mb1})^2}$$

$$\overline{I^2_{n,in}} = \frac{1}{C_{ox}f}\left[\frac{g^2_{m2}K_N}{(WL)_2} + \frac{g^2_{m3}K_P}{(WL)_3}\right]$$

(Total Noise found by adding together the Vn and In expressions above.)

Source followers (Common-Drain)

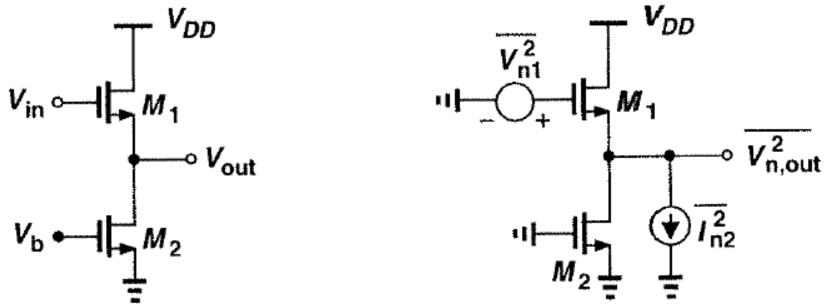


Figure 7.42 (a) Source follower, (b) circuit including noise sources.

In can often be ignored

$$\overline{V_{n,in}^2} = \overline{V_{n1}^2} + \frac{\overline{V_{n,out}^2 |_{M2}}}{A_v^2} = 4kT\frac{2}{3}\left(\frac{1}{g_{m1}} + \frac{g_{m2}}{g_{m1}^2}\right)$$

Often avoided in LP setups due to that they add noise on the input signal while the voltage gain is less than 1.

Cascode Stage

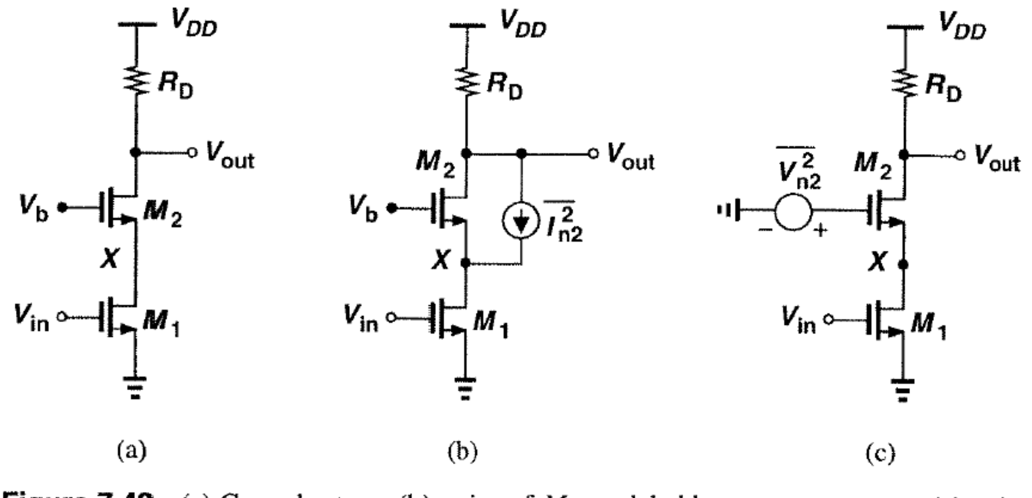


Figure 7.43 (a) Cascode stage, (b) noise of M_2 modeled by a current source, (c) noise of M_2 modeled by a voltage source.

$$\overline{V_{n,in}^2} |_{M1,RD} = 4kT\left(\frac{2}{3g_{m1}} + \frac{1}{g_{m1}^2 R_D}\right)$$

SNR is the signal/noise ratio when the signal is present. SNR_{max} is the ratio between the maximum signal S_{max} and noise (N_{max}) that is present at the maximum signal. SNR_{min} is the ratio between the minimum signal *Smin* and the noise level (*Nmin*) in this case. Since the noise almost always grows with the signal we will have that $N_{max} > N_{min}$.

DR (Dynamic Range) is the ratio between the maximum signal and the noise at the minimal signal. Hence we will always have $DR \geq SNR$.

$$SNR_{Max} = \frac{S_{Max}}{N_{Max}}$$

$$SNR_{Min} = \frac{S_{Min}}{N_{Min}}$$

$$DR = \frac{S_{Max}}{N_{Min}}$$

Generally we will have that:

$$DR >> SNR_{Max} >> SNR_{Min}$$