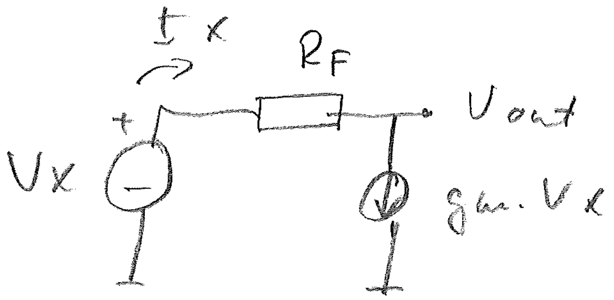
1. See Tutorial 1, problem 4

2. Small signal model

a)



Small signal model for Rin.

$i_x = g_m \cdot V_x$ $\quad$ $R_{in} = \frac{V_x}{i_x} = \frac{1}{g_m}$

b) Gain from point X: $\frac{V_{out} - V_x}{R_F} + g_m \cdot V_x = 0$

$\Leftrightarrow$

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

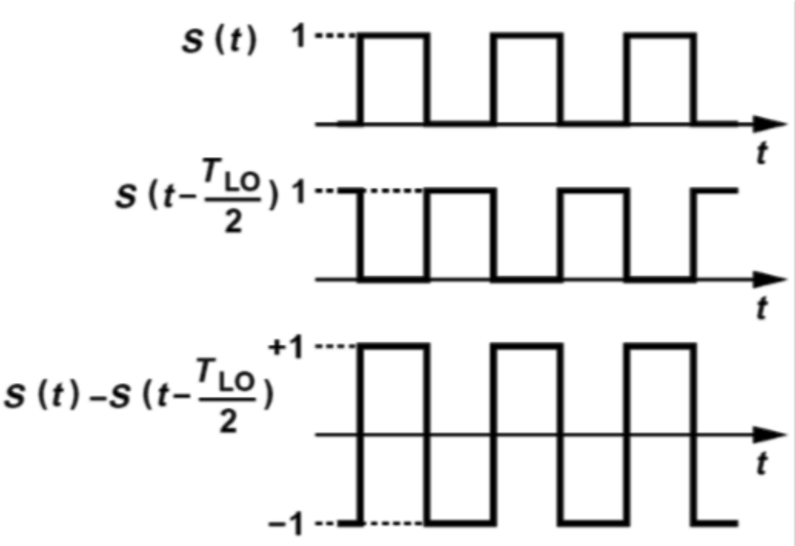
$$V_x = \frac{1/g_m}{1/g_m + R_s} \cdot V_{in} \Rightarrow A_v = \frac{V_{out}}{V_{in}} = \frac{\frac{1}{g_m}}{1/g_m + R_s} \cdot (1 - g_m \cdot R_F)$$

$$= \frac{1}{2}\left(1 - \frac{R_F}{R_s}\right). \quad R_F = 25 R_s \Rightarrow A_v = \frac{1}{2}\left(1 - \frac{25}{1}\right) = -12$$

c) $\overline{V_{n,out}^2} = 4kTR_s \cdot A_v^2 = 4kTR_s \cdot \frac{1}{4}\left(1 - \frac{R_F}{R_s}\right)^2$

If $R_F = 25 R_s \Rightarrow \overline{V_{n,out,R_s}^2} = 4 \cdot kTR_s(-12)^2 = 576\, kTR_s$

3.



$$V_{out}(t) = I_{RF}R\,[S(t) - S(t - T_{LO}/2)] = I_{RF}R \cdot \frac{4}{\pi}\cos(\omega_{LO}t) + ...$$

If $V_{RF} = A_{RF}\cos(\omega_{RF}t)$, then by ignoring the higher order terms:

$$V_{out}(t) = \frac{4}{\pi}g_{m3}RA_{RF}cos(\omega_{RF}t)cos(\omega_{LO}t)$$
$$\rightarrow V_{IF} = \frac{2}{\pi}g_{m3}RA_{RF}cos((\omega_{RF} - \omega_{LO})t)$$

Therefore the conversion gain is:

$$G_C = \frac{V_{IF}}{A_{RF}} = \frac{2}{\pi}g_{m3}R$$

4.

See the Razavi course book, Example 8.14 and Figure 8.26. Here instead we have Q=5 @ 2.45 GHz => Q*(L1+L2)*ω = 154 Ω. (L1 = L2 = 1 nH each!)

g_m for the transistors > 154/2 = 77 Ω^{-1}.

5.

Similar to Fig 9.30 in the course book and eq. 9.17 - 9.19.

The solution can also be written as:

Open loop transfer functions of the system is:

$$H_o(s) = K_{PFD} Z_{LPF}(s) \frac{K_{VCO}}{s} = \frac{I_o}{2\pi} \left(\frac{1}{sC_p} + R \right) \frac{K_{VCO}}{s}$$

$$H_o(s) = \frac{I_0 K_{VCO}}{2\pi C_p} \frac{1 + sRC_p}{s^2} = k \frac{1 + sRC_p}{s^2} \quad \text{, where } k = \frac{I_0 K_{VCO}}{2\pi C_p}$$

The close-loop transfer function is then:

$$H(s) = \frac{H_0(s)}{1 + H_0(s)} = k \frac{1 + sRC_p}{s^2 + sRC_p k + k}$$

6. a) 24 dBm average, PAPR = 5 dB, network losses = 1.5 dB ⇒ 24 + 5 + 1.5 = 30.5 dBm peak power.

30.5 dBm (≈ 1 W) = 1122 mW

b) $P = \frac{V_P^2}{2R_L}$ where $V_P \approx V_{DD}$ (simplest approx.)

$\Leftrightarrow \quad R_L = \frac{V_P^2}{2P}$ $\qquad V_P = V_{DD} = 1.8\text{ V}$, $P = 1.122\text{ W}$

$\Rightarrow \quad R_L = 1.4\ \Omega$

[Transformation ratio = $\frac{50\ \Omega}{1.4\ \Omega}$ = 35x, not so easy to do, generally ratio should not be larger than 10.]

c) Cascode gives possibility of higher supply voltage.

Linear PA ⇒ V_X may reach $2 \times V_{DD}$

65 nm CMOS (as an example): each transistor can safely handle ~1.8 V ⇒ cascode (although usually not evenly distributed over the two transistors).

7. Please provide short answers (no motivations are needed) to the following questions:

a) For RF-circuits, a design aspect is associated with the names Stern or Rollett. What design aspect?

Stability, i.e. lack of self-oscillations. Book section 5.1 mentions Stern. But most commonly the stability factor is referred to as Rollett's stability factor.

b) If changing the circuit topology from a single-balanced to a double-balanced mixer, what happens with the conversion gain? (0.5 p)

It stays the same. Book Examples 6.6 and 6.7.

c) Can the fringe (grid) capacitor used in advanced CMOS processing be used as a varactor? (0.5 p)

No, it is a fixed capacitance structure. It is a metal-plate capacitor with silicon dioxide or combinations of passivation material between the metal layers. Book section 7.6.2.

d) Circuit types/names like Clapp, Colpitt, and Hartley are associated with a certain type of radio building blocks. What type? (0.5 p)

Oscillators ("three-point oscillators"). Book section 8.4.