ECE164/ECE264A Problem

The questions below relate to the following amplifier circuit. While solving them you may assume that

(i) capacitances $C_1$ and $C_2$ are sufficiently large that the small-signal transistor model capacitances may be neglected,
(ii) both transistors are in saturation,
(iii) both the current sources are ideal, and
(v) $r_{ds} \gg 1/g_{m}$ for all values of $i$ and $j$.

Note: **You only need to answer three of the following four questions.** You are free to choose which question to skip. If you attempt all four questions, be sure to indicate which three of them should be graded. Otherwise, the decision will be made randomly by the grader.

1) Derive a block diagram of the circuit with input $v_{in}(s)$, output $v_{out}(s)$, and nodes corresponding to $v_{gs1}(s)$ and $v_{ds1}(s)$.

2) Derive an expression for $A_v(s) = v_{out}(s)/v_{in}(s)$ using Mason’s Gain Formula. You need not reduce your final answer to its simplest form.

3) Derive an expression for the output resistance of the circuit using Blackaman’s Impedance Relation. For this problem only, you may neglect capacitors $C_1$ and $C_2$ as well the transistor model capacitances.

4) Suppose $R_1 = 3\, \text{k}\Omega$, $R_2 = 9\, \text{k}\Omega$, $g_{m1} = 10^{-3} \, \text{mS}$, $g_{m2} = 10^{-4} \, \text{mS}$, $r_{ds1} = 100 \, \text{k}\Omega$, $r_{ds2} = 200 \, \text{k}\Omega$, $C_1 = 50 \, \text{fF}$, and $C_2 = 3 \, \text{pF}$. Calculate the DC gain and approximate 3dB bandwidth of the amplifier.
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1) If $Z_L = 40 + j30 \Omega$ and the 50 Ohm resistor is the source resistance, which impedance matching network in Figure 1 would you use? Justify your answer.

2) Find the impedance, X, and susceptance, B, for the matching network you chose in Problem 1.

3) If the matching network is not used what is the return loss as seen from the source in dB.

4) Consider the receiver shown in Figure 2. It consists of an antenna, an RF amplifier, a SSB mixer, a bandpass IF filter, and a bandpass ADC. What is the receive chain gain in dB of the receiver shown in Figure 2?

5) What is the single sideband noise figure of the receiver shown in Figure 2 referenced at the antenna?

6) Now consider the RF amplifier in Fig. 3 that is used in your receiver chain. What is the IIP3 of the BJT amplifier? Assume $V_t = 25mV$. Remember that the Taylor series is

$$f(x) = f(a) + f'(x-a) + f''(x-a)/2 + f'''(x-a)/6 \text{ and } IIP^3 = \frac{\left| a_3 \right|}{\sqrt{\left| a_1 \right|}}$$