Final Exam: ENEE 307

Part I. (34pts.) Difference Amplifier with Current Mirror as DC Current Source in Figure 1. Include the effects of gm. Take Vbe = 0.7 for DC bias. Assume all BJT's are identical. β=200, V_T = 25mV (Thermal voltage). For this circuit, assume midband frequencies.

1. Verify that the value of I_{EE} = 2.0mA. If you cannot show this, don't worry about it, just use this value of Iee = 2.0mA as the DC current source and do rest of the problem.
2. Explain qualitatively in a sentence or two how a current mirror works.
3. What is the AC gain of this circuit?
4. Show how you would connect an emitter follower at Q2 to construct an elementary op-amp.
5. Show how you would connect a feedback loop using two resistors Ra and Rf to obtain a non-inverting amplifier. and
6. Derive the expression for the closed loop gain from for a non-inverting amplifier. (Neglect loading effects here.) Leave your expression in terms of Ra and Rf and other appropriate parameters like gm, and resistor values.

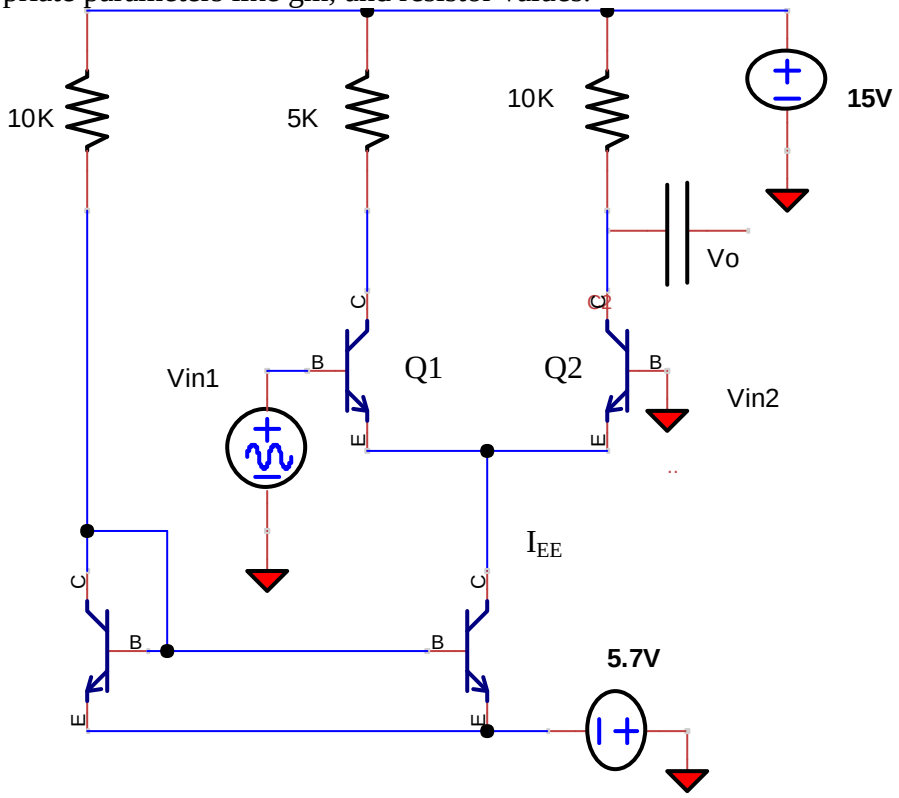


Figure 1

gm = I / Vt gm = (KW/L)(VGS-VTH)

Id = $[(KW/(2L)](VGS-VTH)^2$ (this is for saturation region of MOSFET operation)

P_L = - Σ $[(1/(R_iC_i)]$ P_H = - $1/[\Sigma (R_iC_i)]$

RTB = β/gm + βRE RTE = 1/gm + RS/ β RTC = infinity

C_M = C(1+|Av|) dB = 20 log |Av(ω)|

Part II. (33 pts.): The following questions refer to the Common Source Amplifier in Figure 2. For the MOSFET in the figure K = 1.0×10^{-4} A/V^2, W=4um, L=2um, V_{TH} = 1.0V. Cgs=2.0pF, Cgd = 1.0pF, C1 = 0.1uF, C2 = 0.1uF.

1. Determine the DC bias voltages and currents: Id, Is, Ig, Vd, Vg and Vs.
2. Calculate the midband voltage gain.
3. Use Miller's theorem to find the high frequency pole of this circuit (P_H)
4. If the input is Vin(t) = $0.5\sin(2\pi 10^9 t)$, calculate the output as a function of time.
5. Is the MOSFET is saturation, why?
6. If the capacitor C1 removed so the 1K is directly connected to the gate, what will the DC value of Vg become, and explain in a sentence what will happen to the operation of the circuit.

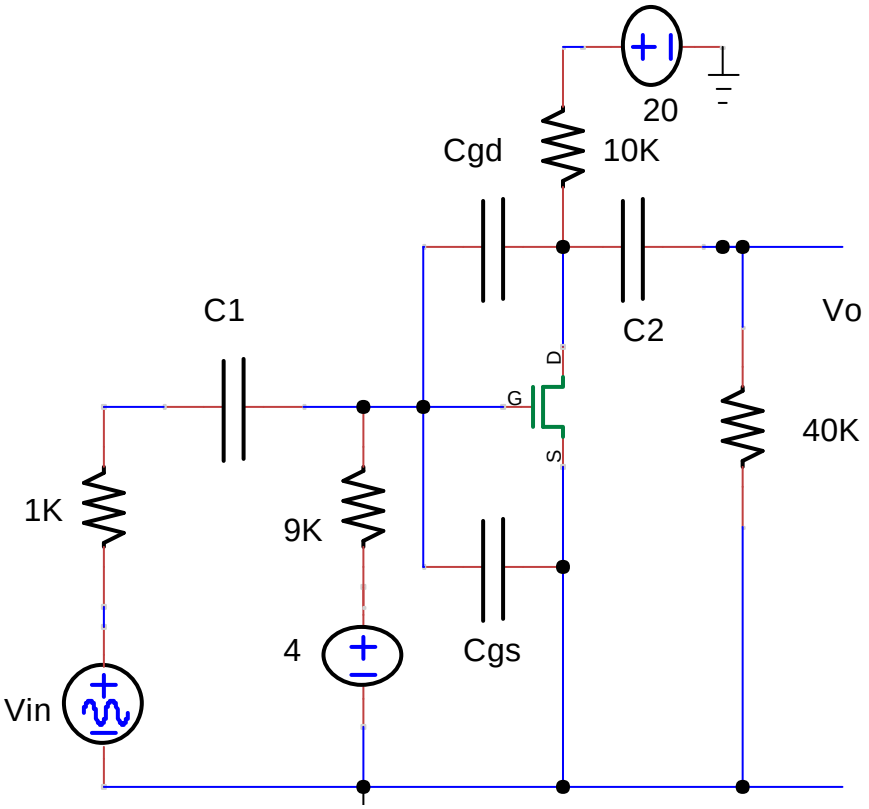


Figure 1

Part III. (33pts). Analyze the Common Emitter Amplifier circuit in Figure 2 at midband frequencies. (Ignore AC capacitive effects). β=200. Include the effects of gm, but you can make simplifying approximations if you briefly justify them. Take Vbe = 0.7 for DC bias.

1. Determine the DC voltage values at the collector and emitter.
2. Determine the small signal voltage gain, don't forget to account for the effects of Rs = 1K and RL=15K.
3. If an input signal to be Vs(t) = $0.2\sin(2\pi 10^7 t)$, Sketch the complete signal at V_C and V_E for two periods, include the DC offsets. Carefully label your axes. (For this question, ignore frequency effects.)
4. Now consider low frequency effects. Use the short circuit time constant approximation to calculate the low frequency pole of this circuit.
5. Draw and label a Bode plot of voltage gain versus frequency for low and midband.
6. If the input signal to be Vs(t) = $0.2\sin(2\pi 10^1 t)$, sketch the complete signal at Vout for two periods. Carefully label your axes. If necessary, consider the frequency effects in your answer.

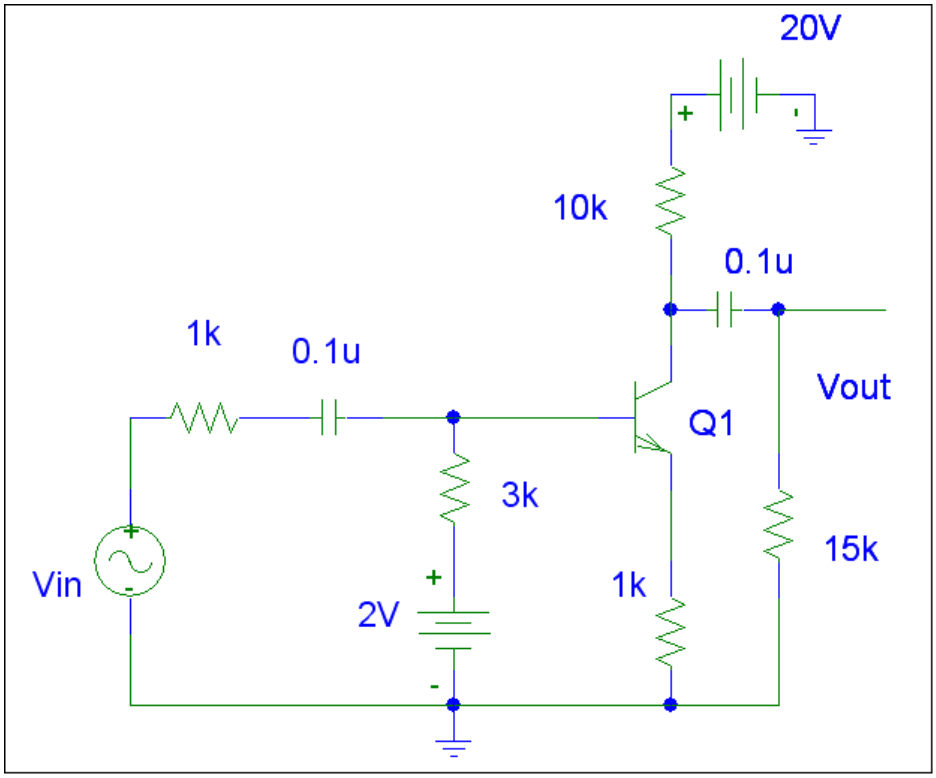


Figure 3