American University of Beirut

Department of Electrical and Computer Engineering

EECE 311 – Electronic Circuits

Spring 2011

Midterm – April 8, 2011

Open Book – 120 minutes

NAME: ___________ANSWERS___________ **ID Number:** ______________________

- All questions are equally graded
- **PENALTY** is four-to-one (four wrong answers cancel one correct answer, one to three wrong answers have no effect)
- Grading is based on the answers marked on the SCANTRON sheet only.

Assume that:

- $V_{BE(active)} = 0.7$ V $V_{CE(edge\ of\ sat)} = 0.3$ V
- $V_T = 25$ mV
- MOSFET channel-length modulation and BJT Early effect can be neglected during DC analysis.
- MOSFET channel-length modulation and BJT Early effect can be neglected in small-signal analysis, unless you are specifically requested to include them.

1. Consider the transfer function:

$$F_H(s) = \frac{1 - \frac{s}{10^6}}{\left(1 + \frac{s}{5 \times 10^3}\right)\left(1 + \frac{s}{5 \times 10^5}\right)\left(1 + \frac{s}{6 \times 10^6}\right)}$$

Find the 3-dB frequency (in Hz) using the most appropriate method.

a) 795.8 b) 159.2 c) 318.3 d) 477.5 e) 636.6

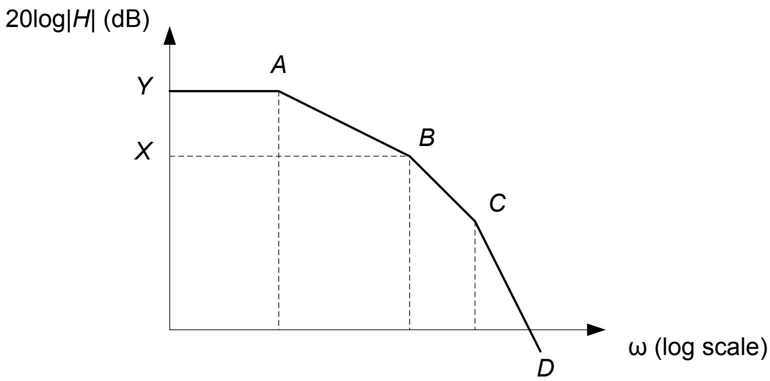
2. Consider the transfer function:

$$F_H(s) = \frac{1 - \frac{s}{2400}}{\left(1 + \frac{s}{2000}\right)\left(1 + \frac{s}{4000}\right)}$$

Find the *exact* value of the 3-dB frequency (in krad/s).

a) 1.77 b) 2.37 c) 6.21 d) 3.03 e) 1.87

3. Given the following asymptotic Bode plot of a 3-pole no-zero transfer function $H(s)$, with poles at $\omega_A = 10$ rad/s, $\omega_B = 30$ rad/s, and $\omega_C = 40$ rad/s.



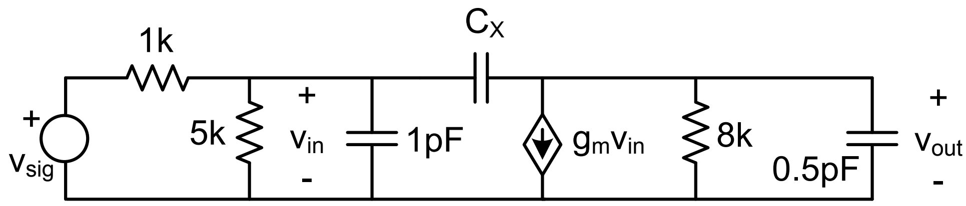
What is the slope of segment CD?

a) –40 dB/decade b) –60 dB/decade c) –20 dB/decade
d) –15 dB/octave e) –12 dB/octave

4. Find X (in dB) in the previous problem if $Y = 32$ dB.

a) 43.5 b) 10.5 c) 15.5 d) 37.5 e) 22.5

5. Using the Open-Circuit Time Constants (OCTC) method, the 3-dB frequency for the amplifier whose small-signal equivalent circuit is shown below was found to be 100 kHz. Find the value of the capacitor C_X (in pF). Assume g_m = 4 mA/V.

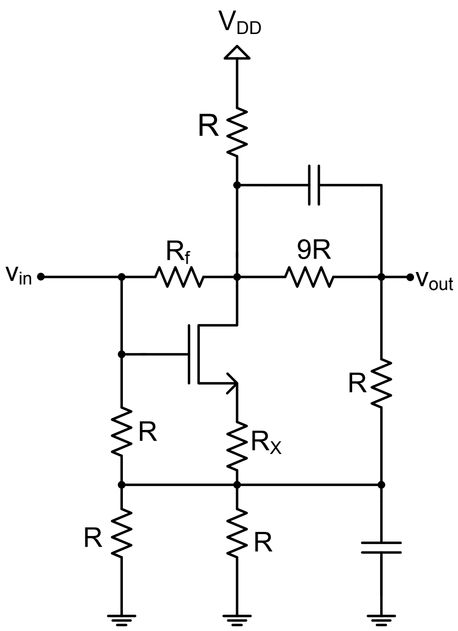


a) 28.6 b) 32.5 c) 55.0 d) 37.6 e) 44.7

6. In the circuit of the previous problem, and after using Miller's theorem, the total capacitance on the input side of the circuit was found to be 120 pF. Find the value of the capacitor C_X (in pF). Assume g_m = 4 mA/V.
Note: Miller's constant K is calculated assuming all capacitors are open circuits.

a) 2.09 b) 2.90 c) 2.43 d) 4.76 e) 3.61

7. The amplifier shown in the figure below is a common-

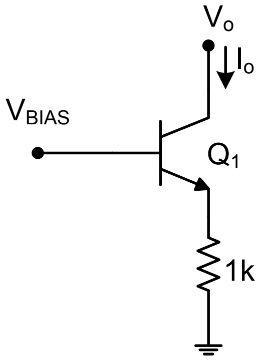


a) source b) gate c) drain d) base e) collector

8. Find the voltage gain (in absolute value) of the amplifier in the previous problem, v_{out}/v_{in}, if g_m = 1 mA/V for the MOSFET, R = 11 kΩ and R_X = 100 Ω. Assume that all capacitors are very large with negligible impedance at signal frequencies. Also assume that R_f is a *very* large resistor.

a) 2.3 b) 3.2 c) 4.1 d) 5.0 e) 5.9

9. The voltage at the emitter of transistor Q_1 in the current source circuit shown below was measured to be 0.26 V. Find the minimum output voltage (in V) to maintain current source operation for the circuit.

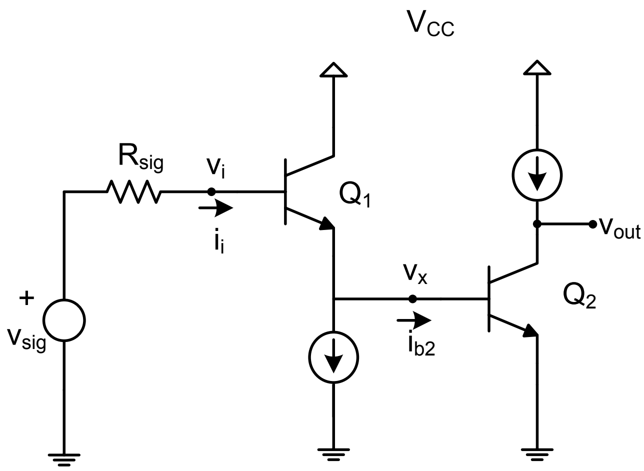


a) 2.4 b) 0.43 c) 0.56 d) 0.9 e) 1.5

10. Find the output resistance (in MΩ) of the current source in the previous problem. For the BJT, $\beta = 100$, and the Early voltage is 50 V. V_{BIAS} is a pure DC source.

a) 1.4 b) 1.1 c) 2.3 d) 2.0 e) 1.7

Questions 11 to 16: The CC-CE pair shown below uses transistors that are biased such that for both BJTs, $g_m = 25$ mA/V, $\beta = 90$, and $r_o = 100$ kΩ. The two current sources used to bias the BJTs have small-signal output resistances equal to 50 kΩ. The signal source resistance is $R_{sig} = 100$ kΩ.



11. Find the gain of the CE stage, v_{out} / v_x.

a) –833.3 b) –1000 c) –333.3 d) –500 e) –666.7

12. Find the input resistance of the CE stage, v_x / i_{b2} (in kΩ).

a) 3.0 b) 9.0 c) 6.0 d) 4.5 e) 3.6

13. Find the input resistance of the amplifier, v_i / i_i (in kΩ).

a) 365.3 b) 253.4 c) 299.3 d) 653.9 e) 468.7

14. Find output resistance of the amplifier (in kΩ).

a) 50 b) 33.3 c) 100 d) 20.6 e) 67.5

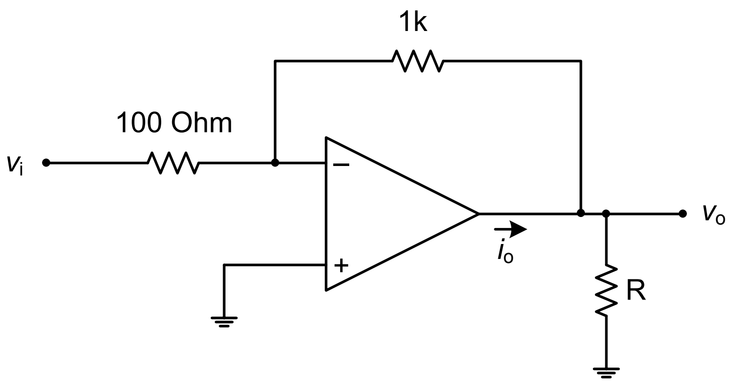
15. Using OCTC, find the resistance seen by C_π of transistor Q_2 (in Ω).

a) 1025 b) 948 c) 890 d) 843 e) 802

16. Using OCTC, find the resistance seen by C_μ of transistor Q_1 (in kΩ).

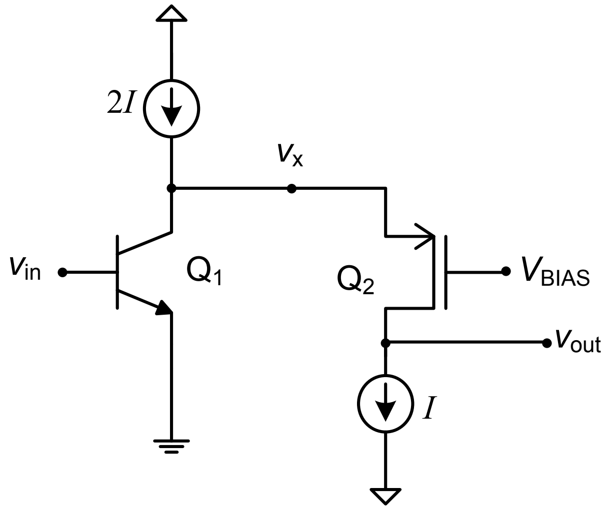
a) 82.4 b) 78.5 c) 74.9 d) 71.7 e) 86.7

17. The op-amp in the circuit shown produces an output voltage in the range –10 V to +10 V. The maximum output current $i_{o(max)}$ is 10 mA. The slew-rate of the op-amp is specified to be 10 V/µs. Assuming R = 500 Ω and $v_i = 2\sin(100t)$ V, what is the maximum value of v_o (in V)?



a) 1.67 b) 2.31 c) 2.86 d) 3.33 e) 3.75

Questions 18 to 22: Consider the amplifier circuit shown below. The bias currents are chosen such that for the BJT, $g_{m1} = 4$ mA/V, $r_{o1} = 500$ kΩ, while for the MOSFET, $g_{m2} = 0.11$ mA/V, $r_{o2} = 100$ kΩ. The small-signal output resistance of the $2I$ current source is r_{o1}, while the I current source biasing the MOSFET is *ideal*.



18. Find the output resistance of the amplifier (in MΩ).

a) 3.35 b) 3.60 c) 3.85 d) 3.10 e) 2.85

19. Find the voltage gain of the second stage, v_{out} / v_X.

a) 15 b) 12 c) 13 d) 14 e) 11

20. Find the gain of the first stage, v_X / v_{in}.

a) –1000 b) 1000 c) –1500 d) 2000 e) –2000

21. Use the OCTC method to find the 3-dB frequency of the amplifier circuit. Let $C_X = 5$ pF be the equivalent capacitance at the collector node of the BJT to ground. Neglecting the effect of all other capacitances, find $\omega_{3\text{-dB}}$ (in Mrad/s).

a) 0.5 b) 4 c) 2 d) 1 e) 0.8

22. Assume now that for the MOSFET $k'W/L = 2$ mA/V^2 and $V_t = -1$ V. Let $I = 360$ μA and $V_{BIAS} = 1$ V. Find the value of V_{CE} for the BJT (in V).
Hint: Start by finding V_{GS} of the MOSFET.

a) 2.51 b) 2.60 c) 2.40 d) 2.14 e) 2.28