American University of Beirut

Department of Electrical and Computer Engineering

EECE 311 – Electronic Circuits

Spring 2009

Midterm – April 15, 2009

Open Book – 120 minutes

NAME:____________________________ **ID Number:** _______________________

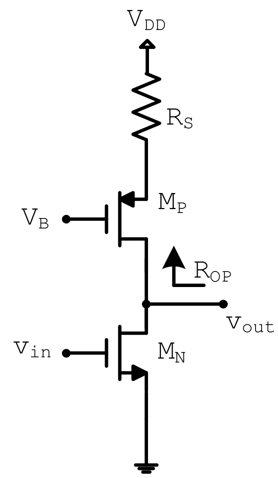
- All questions are equally graded
- PENALTY is **four-to-one** (four wrong answers cancel one correct answer, one to three wrong answers have no effect)
- Grading is based on the answers marked on the SCANTRON sheet only.

Assume that:

The DC drain current of a MOSFET in SAT is given by $I_D = \frac{1}{2}k'\left(\frac{W}{L}\right)(V_{GS} - V_t)^2$.

The DC collector current of a BJT in ACTIVE is given by $I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right)$, and V_T = 25 mV.

The common-source amplifier shown is loaded by a PMOS current source *with a source resistor* R_S. The inclusion of R_S must raise the output resistance of the PMOS current source to ten times r_{oN} (i.e. $R_{OP} = 10r_{oN}$). Assume that the MOSFETs are biased at a drain current of 0.5 mA. V_B is a DC source. The MOSFET parameters are:
$k_n' = 0.2$ mA/V^2, $V_{tn} = 0.5$ V, $\lambda_n = 0.1$ V^{-1}, $k_p' = 0.1$ mA/V^2, $V_{tp} = -0.6$ V, $\lambda_p = 0.1$ V^{-1}.



1. Find the value of R_S (in KΩ) if $(W/L)_P = 150$.
(a) 1.82 (b) 1.99 (c) 3.13 (d) 2.67 (e) 2.29

2. Determine the value of $(W/L)_N$ to obtain a voltage gain of –30.
(a) 9.45 (b) 6.05 (c) 24.2 (d) 18.5 (e) 13.6

3. What is the output voltage swing (maximum – minimum, in V) to ensure saturation region operation for both MOSFETs? Assume $V_{DD} = 3$ V.
(a) 0.63 (b) 0.84 (c) 1.0 (d) 2.0 (e) 3.0

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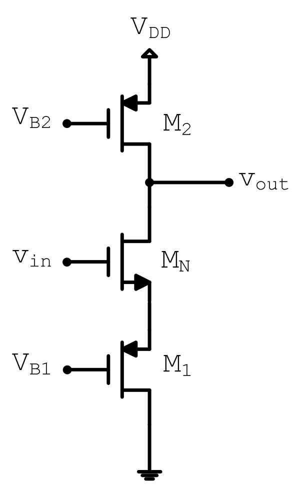
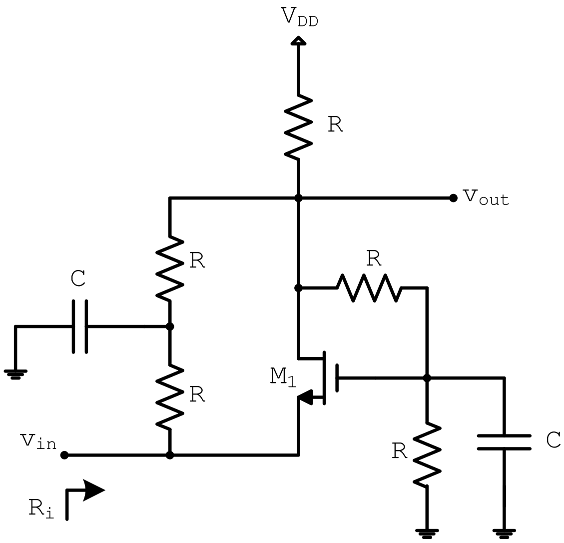
4. Find the voltage gain v_{out}/v_{in} of the amplifier shown. Assume all MOSFETs have the same g_m and that transistor M_N has a *long channel* (i.e. $\lambda = 0$), while $r_{o1} = r_{o2} = 36/g_m$.
V_{B1} and V_{B2} are DC voltages.
(a) –16.1 (b) –24.1 (c) –22.1 (d) –20.1 (e) –18.1



In the circuit shown below, the MOSFET has a long channel ($\lambda = 0$) and is biased such that its transconductance g_m = 1 mA/V. The resistors are all equal to 21 KΩ. The capacitors are very large.



5. Identify the type of amplifier stage. It is common-
(a) follower (b) source (c) drain (d) gate (e) emitter

6. Find the voltage gain v_{out}/v_{in}.
(a) 4 (b) 5 (c) 6 (d) 7 (e) 8

7. Find the input resistance R_i in KΩ.
(a) 15/16 (b) 18/19 (c) 24/25 (d) 12/13 (e) 21/22

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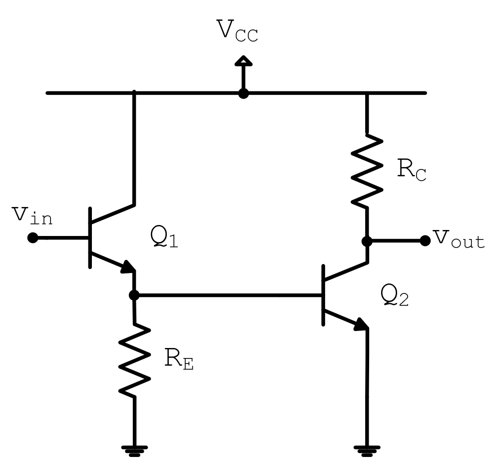
8. Calculate the input resistance of the circuit shown below, in KΩ. The BJTs are biased at a collector current of 1 mA and have β = 100 and V_A = 50 V. Assume R_C = 12 KΩ and R_E = 0.6 KΩ.
(a) 57.1 (b) 50.9 (c) 29.4 (d) 37.1 (e) 44.2



9. Calculate the output resistance of the circuit in KΩ. All circuit elements are an internal part of the amplifier.

(a) 8.33 (b) 9.68 (c) 10.9 (d) 6.89 (e) 5.36

10. Find the voltage gain v_{out}/v_{in}.

(a) –367.9 (b) –314.3 (c) –195.9 (d) –418.2 (e) –257.1

11. Find the current gain of the amplifier when a 10 KΩ load is connected at the output (from the collector of Q_2 to ground). The output current is that flowing in the load resistor, while the input current comes from v_{in}.

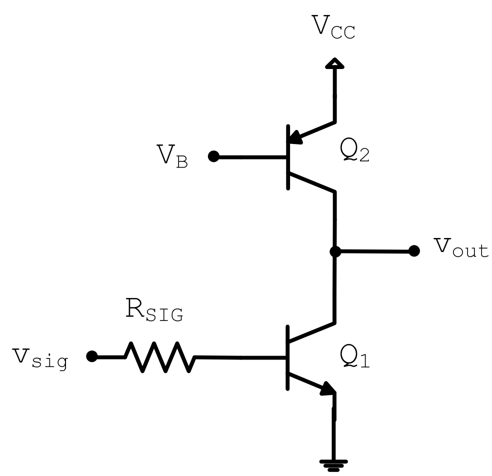
(a) –1141.2 (b) –951.7 (c) –758.4 (d) –375.2 (e) –564.3

The two BJTs in the circuit shown below are biased such that:

$r_{\pi1}$ = 4 KΩ, r_{o1} = 80 KΩ, $g_{m1} = g_{m2}$ = 30 mA/V, $r_{\pi2}$ = 3 KΩ, and r_{o2} = 12 KΩ.

Also assume that $C_{\pi1} = C_{\pi2}$ = 0.2 pF and $C_{\mu1} = C_{\mu2}$ = 0.1 pF.

The signal source resistance is R_{SIG} = 10 KΩ.



12. Using Miller's theorem, find the total equivalent capacitance (in pF) that appears between the base of Q_1 and ground.

(a) 57.4 (b) 27 (c) 31.6 (d) 38.2 (e) 44.4

13. Using Miller's theorem, find the total equivalent capacitance (in pF) that appears between the collector of Q_1 and ground.

(a) 0 (b) 0.3 (c) 0.4 (d) 0.2 (e) 0.1

14. Find the resistance seen by the capacitance of the previous question (in KΩ).

(a) 8.89 (b) 10.4 (c) 12.6 (d) 14.7 (e) 19.0

15. Find the 3-dB frequency (in MHz) using OCTC, considering only the two capacitances obtained in questions 12 and 13.

(a) 1.7 (b) 1.4 (c) 0.95 (d) 2.0 (e) 1.2

The transfer function of an amplifier is given by $A(s) = \dfrac{1+s/\omega_1}{(1+s/\omega_2)(1+s/\omega_3)}$,

where ω_1 = 18,000 rad/sec, ω_2 = 6,000 rad/sec, and ω_3 = 30,000 rad/sec.

16. Find the frequency (in Krad/sec) at which the gain drops by 8 dB from its DC value.
(a) 11.9 (b) 14.3 (c) 17.0 (d) 20.2 (e) 23.9

17. The input to the amplifier is $\sin(\omega_0 t)$ V, where ω_0 = 6600 rad/sec. Find the amplitude (in V) of the output waveform.
(a) 0.4 (b) 0.8 (c) 0.7 (d) 0.6 (e) 0.5

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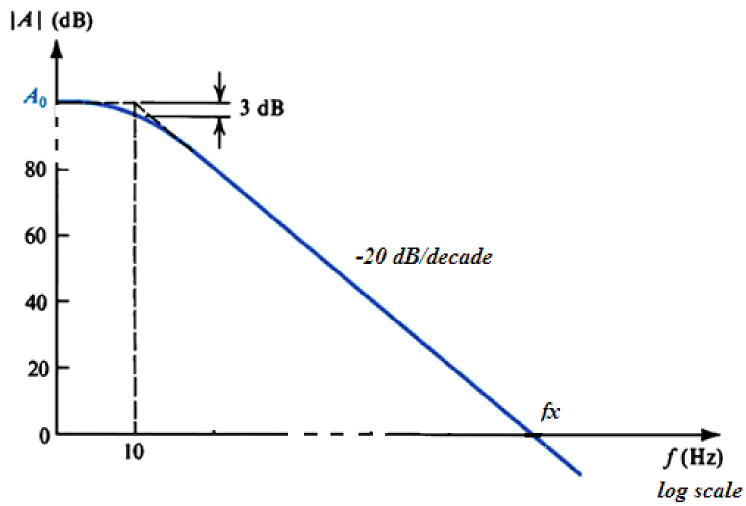
18. Find the frequency f_x (x-axis intercept, in MHz) in the Bode plot shown below. The low-frequency gain A_0 is 180 dB.
(a) 1 (b) 10 (c) 100 (d) 1000 (e) 10,000



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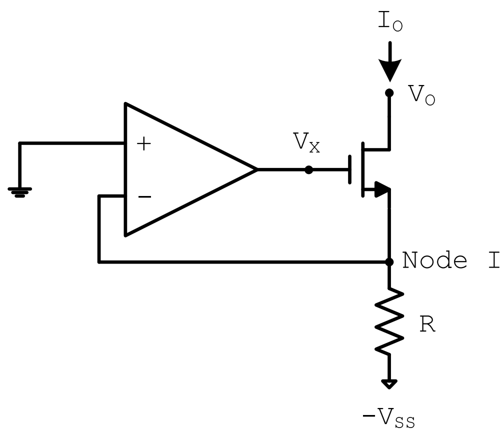
19. What is the maximum frequency (in MHz) of a sinusoidal signal with a 1 V amplitude to be differentiated by an OP-AMP differentiator circuit *without slew-rate distortion*? The slew-rate specification of the OP-AMP is 10 V/μs and the differentiator time constant is 8 ns.
(a) 4.2 (b) 3.8 (c) 7.1 (d) 5.6 (e) 5.0

Assume that the OP-AMP in the circuit shown below is ideal.
Assume also that the MOSFET is in saturation, with small-signal parameters
g_m = 1 mA/V, r_o = 50 KΩ.
The negative supply is $-V_{SS}$ = –2 V and R = 20 KΩ.



20. Find the output current I_O in μA.
(a) 100 (b) 50 (c) 400 (d) 300 (e) 200

21. Find the change in the output current (in μA) when the output voltage increases by +1V.
(a) 50 (b) 0 (c) 20 (d) 0.93 (e) 1

22. A resistor R_X equal to 10 KΩ is now inserted between the source terminal of the MOSFET and Node I. Find the voltage V_X (in V) at the output of the OP-AMP if the MOSFET threshold voltage is 0.7 V.
(a) 1.3 (b) 1.9 (c) 3.1 (d) 5.5 (e) 4.3

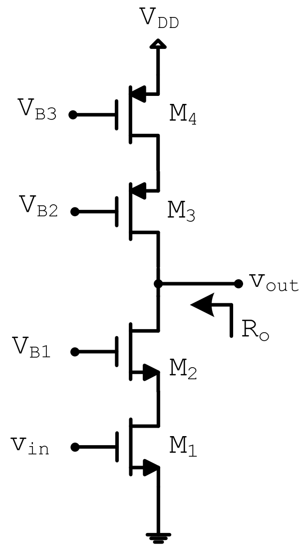
23. R_X is now removed. Find the change in the output current (in nA) when the output voltage increases by +1V if the OP-AMP has a *finite open-loop gain* of 250.
(a) 4 (b) 9.9 (c) 6.6 (d) 5 (e) 3.3

Two amplifiers are cascaded. The first amplifier has an input resistance of 10 KΩ, an output resistance of 10 KΩ, and an *open-circuit* voltage gain function of $\dfrac{90}{1+s/10^5}$. The second amplifier has an input resistance of 20 KΩ, an output resistance of 5 KΩ, and an *open-circuit* voltage gain function of $\dfrac{60}{1+s/3\times10^5}$.

24. Find the overall low-frequency voltage gain of the cascade when a load resistor of 10 KΩ is connected at the output of the second stage.
(a) 1600 (b) 2000 (c) 3200 (d) 2800 (e) 2400

25. Find the overall upper 3 dB frequency f_H (in KHz).
(a) 14.5 (b) 13.3 (c) 15.9 (d) 47.7 (e) 31.8

In the cascode amplifier shown below, all MOSFETs have $(W/L) = 100$ and are biased at a drain current of 0.3 mA.
The MOSFET parameters are:
$k_n' = 0.2$ mA/V^2, $V_{tn} = 0.5$ V, $\lambda_n = 0.1$ V^{-1}, $k_p' = 0.1$ mA/V^2, $V_{tp} = -0.6$ V, $\lambda_p = 0.2$ V^{-1}.



26. Find the required DC bias level in v_{IN} (in V).
(a) 0.765 (b) 0.673 (c) 0.700 (d) 0.724 (e) 0.745

27. Find the output resistance R_O (in KΩ).
(a) 217.2 (b) 284.0 (c) 173.1 (d) 603.7 (e) 394.7

28. The high-frequency response of the amplifier is governed by a load capacitance, connected from the output node to ground. What is the maximum value of this load capacitance (in pF) to have an upper 3-dB frequency of 100 KHz?
(a) 2.64 (b) 4.03 (c) 5.60 (d) 7.33 (e) 9.19

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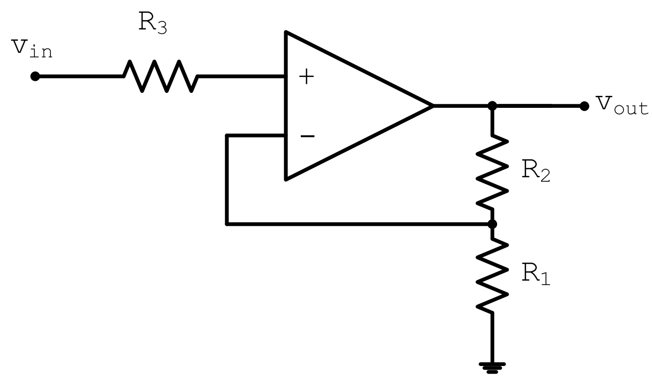
29. Assume that the OP-AMP is ideal in the circuit shown below. The resistors shown in the circuit are R_1 = 10 KΩ, R_2 = 50 KΩ, and R_3 = 10 KΩ. Find the voltage gain v_{out}/v_{in}.
(a) 5 (b) 6 (c) 3 (d) 21 (e) 11



30. Assume now that the OP-AMP specifications show an input bias current of 150 nA, and that the input current flowing into the non-inverting input is two times larger than the current flowing into the inverting input. What DC output voltage (in mV) results due to the input bias current, only (the input v_{in} is zero in this case)?
(a) –1 (b) –5 (c) –37 (d) –17 (e) –7
