UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2007/2008

October/November 2007

EEE 241 – ANALOG ELECTRONICS I
[Elektronik Analog I]

Duration: 3 hours
[Masa: 3 jam]

Please check that this examination paper consists of EIGHT pages of printed material and TWO pages APPENDIX before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi LAPAN muka surat bercetak dan DUA muka surat LAMPIRAN sebelum anda memulakan peperiksaan ini].

This paper contains SIX questions.

[Kertas soalan ini mengandungi ENAM soalan].

Instructions: Answer **FIVE** (5) questions. If a candidate answer more than five questions, only the first five answered will be examined and awarded marks.

*[**Arahan:** Jawab **LIMA** soalan. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah].*

Answer to any question must start on a new page.

[Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru].

You may answer a question either in bahasa Malaysia or in English.

[Anda dibenarkan menjawab soalan sama ada dalam bahasa Malaysia atau bahasa Inggeris].

1. (a) Berikan penerangan secara terperinci mengenai elemen-elemen parasitik yang mesti disertakan dalam litar setara satu transistor npn dwikutub yang terbina daripada proses pengasingan secara simpang yang biasa. Lukis struktur transistor npn dwikutub litar bersepadu dengan semua elemen parasitiknya dan litar setara isyarat kecil transistor dwikutub yang lengkap dengan elemen parasitic ini bagi membantu anda semasa memberi penerangan.

Describe in detail the parasitic elements that must be added to the equivalent circuit of a typical npn junction isolated process bipolar transistor. Draw the integrated-circuit npn bipolar transistor structure showing the parasitic elements and the complete bipolar transistor small signal equivalent circuit to assist you in giving the explanation.

(12 marks)

(b) Berikan penerangan tentang kesan pemodulatan panjang saluran bermula dengan persamaan $L_{eff} = L - X_d$ di mana X_d ialah lebar lapisan susutan di antara titik jepitan fizikal dalam saluran berdekatan salir dengan kawasan salir itu sendiri. L_{eff} ialah panjang saluran efektif. Akhir sekali, berikan ungkapan arus yang menyertakan kesan pemodulatan panjang saluran.

Give your explanation on the channel length modulation effect starting with the expression $L_{eff} = L - X_d$ where X_d is the depletion layer width between the physical pinch-off point in the channel at the drain end and the drain region itself. L_{eff} is the effective channel length. Finally, give the expression for current that includes the channel length modulation effect.

(8 marks)

2. (a) Tentukan Z_i, Z_o dan a_v bagi penguat dalam Rajah 2 jika $k = \frac{\mu_n c_{ox}}{2}\frac{W}{L}$ = 0.3 x 10^{-3}. Diberikan V_t = 3v dan r_o = 100kΩ.

Determine Z_i, Z_o and a_v for the amplifier in Figure 2 if $k = \frac{\mu_n c_{ox}}{2}\frac{W}{L}$ = 0.3 x 10^{-3}. Given V_t = 3v and r_o = 100kΩ.

(10 marks)

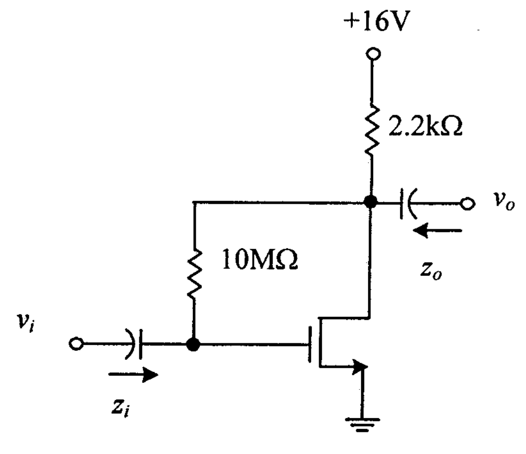
(b) Ulang (a) jika k menurun ke 0.2 x 10^{-3}.
Repeat (a) if k drops to 0.2 x 10^{-3}.

(5 marks)

(c) Bandingkan keputusan dalam (a) dan (b) serta berikan ulasan anda. Penurunan k mungkin disebabkan oleh penurunan nisbah $\frac{W}{L}$.

Compare the results in (a) and (b) and give your comments. The drop in k maybe contributed by the drop in the $\frac{W}{L}$ ratio.

(5 marks)



Rajah 2
Figure 2

3. Diberikan $\beta_F = \beta_O = 150$ bagi kedua-dua Q_1 dan Q_2. Voltan terma atau voltan setara suhu ialah 26mV. $V_A = 100V$ dan $V_{BE} = 0.7V$ bagi kedua-dua transistor.

Given $\beta_F = \beta_O = 150$ for both Q_1 and Q_2. Thermal voltage or temperature equivalent voltage is 26mV. $V_A = 100V$ and $V_{BE} = 0.7V$ for both transistor.

(a) Lukiskan litar setara isyarat kecil bagi penguat berbilang peringkat seperti yang ditunjukkan dalam Rajah 3.

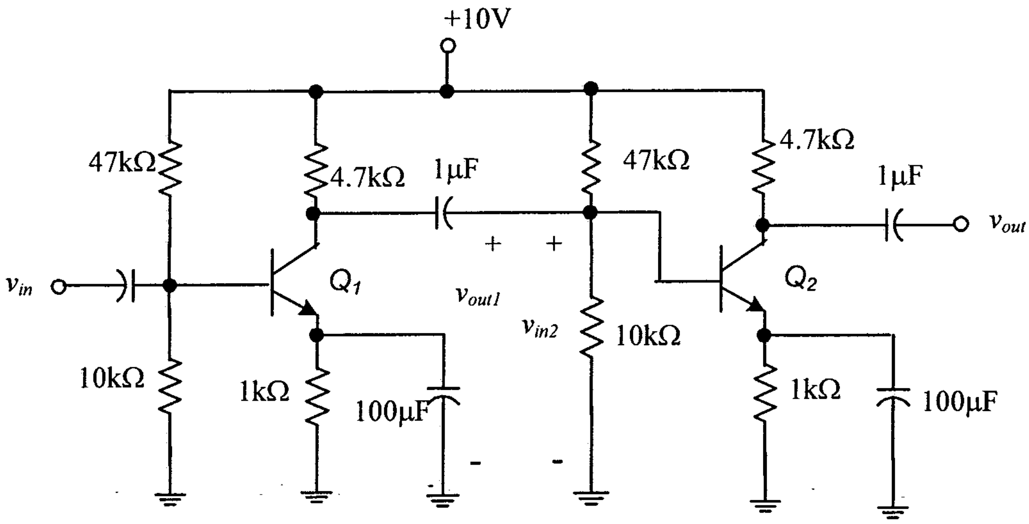
Draw the small-signal equivalent circuit of the multistage amplifier shown in Figure 3.

(5 marks)

(b) Tentukan gandaan voltan bagi peringkat pertama, $\frac{v_{out1}}{v_{in}}$, peringkat kedua, $\frac{v_{out}}{v_{in2}}$ dan gandaan voltan keseluruhan, $\frac{v_{out}}{v_{in}}$.

Determine the voltage gain of the first stage, $\frac{v_{out1}}{v_{in}}$, the second stage, $\frac{v_{out}}{v_{in2}}$ and the overall voltage gain $\frac{v_{out}}{v_{in}}$.

(15 marks)



Rajah 3
Figure 3

4. Tentukan gandaan jalur tengah dan frekuensi 3-dB atas bagi penguat pemancar sepunya yang ditunjukkan dalam Rajah 4. Diberikan,

Determine the midband gain and the upper 3-dB frequency of the common-emitter amplifier shown in Figure 4. Given,

$$V_{CC} = V_{EE} = 10V, \quad I = 1mA$$

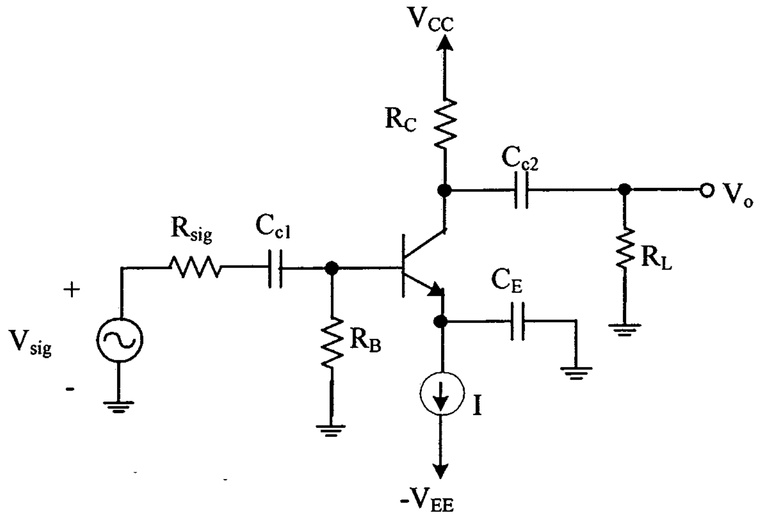
$$R_B = 100k\Omega, \quad R_C = 8k\Omega$$

$$R_{sig} = 5k\Omega, \quad R_L = 5k\Omega$$

$$\beta_o = 100, \; V_A = 100V, \; C_\mu = 1pF$$

$$f_t = 800MHz \; and \; r_b = 50\Omega$$

(12 marks)



Rajah 4
Figure 4

(b) Bagi penguat yang sama dengan yang ditunjukkan dalam Rajah 4 dan dengan keadaan litar seperti yang diberikan dalam (a), tentukan nilai R_L yang dapat mengurangkan gandaan jalur tengah kepada setengah daripada nilai yang telah didapatkan dalam (a). Apakah nilai f_H yang terhasil disebabkan oleh perubahan ini? Berikan komen anda tentang keputusan yang didapati.

For the same amplifier in Figure 4 and with the circuit condition as described in (a), find the value of R_L that reduces the midband gain to half the value found in (a). What value of f_H results from this modification? Give your comments on the results obtained.

(8 marks)

5. (a) Berikan definisi bagi setiap jenis penguat kuasa.

Give the definition for each type of the power amplifier.

($7\frac{1}{2}$ marks)

(b) Bagi litar yang ditunjukkan dalam Rajah 5, kirakan kuasa masukan, kuasa keluaran dan kuasa yang dikendalikan oleh setiap transistor keluaran serta kecekapan litar bagi masukan 12V pmkd.

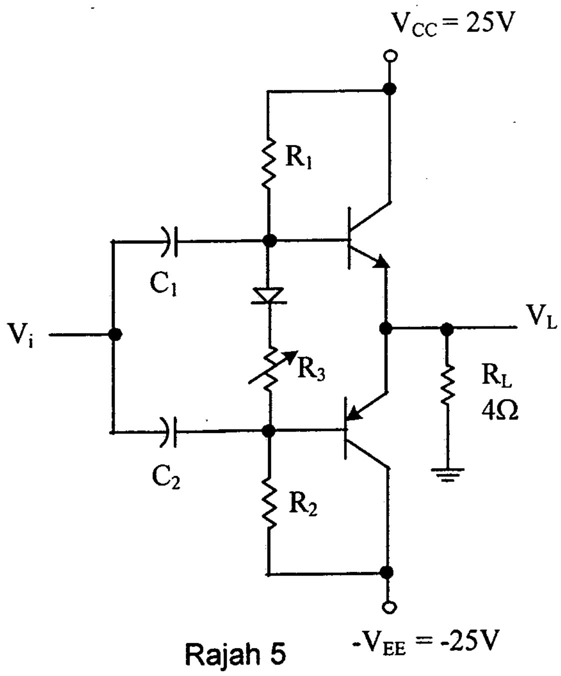
For the circuit shown in Figure 5, calculate the input power, output power and power handled by each output transistor, and finally the circuit efficiency for an input of 12V rms.

(8 marks)

(c) Bagi litar dalam Rajah 5, kirakan kuasa masukan maksimum, kuasa keluaran maksimum, voltan masukan bagi operasi kuasa maksimum dan kuasa yang dilesapkan oleh transistor-transistor keluaran pada voltan ini.

For the circuit in Figure 5, calculate the maximum input power, maximum output power, input voltage for maximum power operation and the power dissipated by the output transistors at this voltage.

($4\frac{1}{2}$ marks)



Rajah 5
Figure 5

6. (a) Berikan penerangan mengenai elemen-elemen parasitik dalam model isyarat kecil transistor MOS. Lukis gambarajah keratan rentas satu transistor MOS saluran-n dengan elemen-elemen parasitik ini disertakan bagi membantu anda dalam memberikan penerangan tersebut. Akhir sekali, lukis litar setara isyarat kecil transistor MOS lengkap dengan elemen-elemen parasitik yang dinyatakan.

Describe the parasitic elements in the small signal model for MOS transistors. Draw the cross section of an n-channel MOS transistor with these parasitic elements included to assist you in your explanation. Finally, draw the small signal MOS transistor equivalent circuit.

(10 marks)

(b) Berikan komen anda tentang perbezaan prestasi dari segi rintangan masukan, rintangan keluaran, gandaan voltan dan gandaan arus bagi ketiga-tiga konfigurasi penguat BJT.

Comment on the differences in the input resistance, output resistance, voltage gain and current gain performances of the three BJT amplifier configurations.

(10 marks)

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APPENDIX

A.1.1 SUMMARY OF ACTIVE-DEVICE PARAMETERS

(a) *npn* Bipolar Transistor Parameters

Quantity	Formula
Large-Signal Forward-Active Operation	
Collector current	$I_c = I_S \exp \frac{V_{be}}{V_T}$
Small-Signal Forward-Active Operation	
Transconductance	$g_m = \frac{qI_C}{kT} = \frac{I_C}{V_T}$
Transconductance-to-current ratio	$\frac{g_m}{I_C} = \frac{1}{V_T}$
Input resistance	$r_\pi = \frac{\beta_0}{g_m}$
Output resistance	$r_o = \frac{V_A}{I_C} = \frac{1}{\eta g_m}$
Collector-base resistance	$r_\mu = \beta_0 r_o$ to $5\beta_0 r_o$
Base-charging capacitance	$C_{b'} = \tau_F g_m$
Base-emitter capacitance	$C_\pi = C_b + C_{je}$
Emitter-base junction depletion capacitance	$C_{je} \simeq 2C_{je0}$
Collector-base junction capacitance	$C_\mu = \frac{C_{\mu 0}}{\left(1 - \frac{V_{BC}}{\psi_{0c}}\right)^{n_c}}$

Quantity	Formula
Small-Signal Forward-Active Operation	
Collector-substrate junction capacitance	$C_{cs} = \frac{C_{cs0}}{\left(1 - \frac{V_{SC}}{\psi_{0s}}\right)^{n_s}}$
Transition frequency	$f_T = \frac{1}{2\pi} \frac{g_m}{C_\pi + C_\mu}$
Effective transit time	$\tau_T = \frac{1}{2\pi f_T} = \tau_F + \frac{C_{je}}{g_m} + \frac{C_\mu}{g_m}$
Maximum gain	$g_m r_o = \frac{V_A}{V_T} = \frac{1}{\eta}$

(b) ***NMOS*** **Transistor Parameters**

Quantity	Formula
Large-Signal Operation	
Drain current (active region)	$I_d = \frac{\mu C_{ox}}{2}\frac{W}{L}(V_{gs} - V_t)^2$
Drain current (triode region)	$I_d = \frac{\mu C_{ox}}{2}\frac{W}{L}[2(V_{gs} - V_t)V_{ds} - V_{ds}^2]$
Threshold voltage	$V_t = V_{t0} + \gamma\left[\sqrt{2\phi_f + V_{sb}} - \sqrt{2\phi_f}\right]$
Threshold voltage parameter	$\gamma = \frac{1}{C_{ox}}\sqrt{2q\epsilon N_A}$
Oxide capacitance	$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = 3.45\ \text{fF}/\mu\text{m}^2$ for $t_{ox} = 100$ Å
Small-Signal Operation (Active Region)	
Top-gate transconductance	$g_m = \mu C_{ox}\frac{W}{L}(V_{GS} - V_t) = \sqrt{2I_D\mu C_{ox}\frac{W}{L}}$
Transconductance-to-current ratio	$\frac{g_m}{I_D} = \frac{2}{V_{GS} - V_t}$
Body-effect transconductance	$g_{mb} = \frac{\gamma}{2\sqrt{2\phi_f + V_{SB}}}g_m = \chi g_m$
Channel-length modulation parameter	$\lambda = \frac{1}{V_A} = \frac{1}{L_{\text{eff}}}\frac{dX_d}{dV_{DS}}$
Output resistance	$r_o = \frac{1}{\lambda I_D} = \frac{L_{\text{eff}}}{I_D}\left(\frac{dX_d}{dV_{DS}}\right)^{-1}$
Effective channel length	$L_{\text{eff}} = L_{\text{drwn}} - 2L_d - X_d$
Maximum gain	$g_m r_o = \frac{1}{\lambda}\frac{2}{V_{GS} - V_t} = \frac{2V_A}{V_{GS} - V_t}$
Source-body depletion capacitance	$C_{sb} = \frac{C_{sb0}}{\left(1 + \frac{V_{SB}}{\psi_0}\right)^{0.5}}$

Quantity	Formula
Small-Signal Operation (Active Region)	
Drain-body depletion capacitance	$C_{db} = \frac{C_{db0}}{\left(1 + \frac{V_{DB}}{\psi_0}\right)^{0.5}}$
Gate-source capacitance	$C_{gs} = \frac{2}{3}WLC_{ox}$
Transition frequency	$f_T = \frac{g_m}{2\pi(C_{gs} + C_{gd} + C_{gb})}$