First Semester Examination
Academic Session 2018/2019

December 2018/January 2019

EEE241 – ANALOGUE ELECTRONICS I
(ELEKTRONIK ANALOG I)

Duration : 3 hours
(Masa : 3 jam)

Please check that this examination paper consists of <u>SIX</u> (6) pages and appendix <u>TWO</u> (2) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi <u>ENAM</u> (6) muka surat dan <u>DUA</u> (2) muka surat lampiran yang bercetak sebelum anda memulakan peperiksaan ini.]

<u>Instructions:</u> This question paper consists of **FIVE (5)** questions. Answer **ALL** questions. All questions carry the same marks.

[***<u>Arahan:</u>*** *Kertas soalan ini mengandungi* ***LIMA (5)*** *soalan. Jawab* ***SEMUA*** *soalan. Semua soalan membawa jumlah markah yang sama.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. (a) Design an active single-pole low-pass filter using an op amp with f_H = 3 kHz, R_{in} = 10 kΩ and A_v = 26 dB. Then pick the closest values for R and C from the Appendix A and recalculate the final f_H. Sketch and give the expression of $A_V(s)$ for the mentioned circuit.

Reka bentuk satu litar aktif kutub-tunggal penapis jalur-rendah menggunakan op amp dengan nilai f_H = 3 kHz, R_{in} = 10 kΩ dan A_v = 26 dB. Kemudian pilih nilai R dan C yang terdekat daripada Appendik A dan kira nilai akhir f_H. Lakarkan dan nyatakan ungkapan untuk nilai $A_V(s)$ litar berkenaan.

(50 marks/*markah*)

(b) Consider the circuit as shown in Figure 1. By applying appropriate assumptions, show that the input resistance R_{in} of the circuit is equivalent to:

$$R_{in} = R_{id}\ (1 + T)$$

Pertimbangkan litar seperti di dalam Rajah 1. Dengan menggunakan andaian yang bersesuaian, tunjukkan bahawa rintangan masukan R_{in} bagi litar tersebut adalah bersamaan dengan:

$$R_{in} = R_{id}\ (1 + T)$$

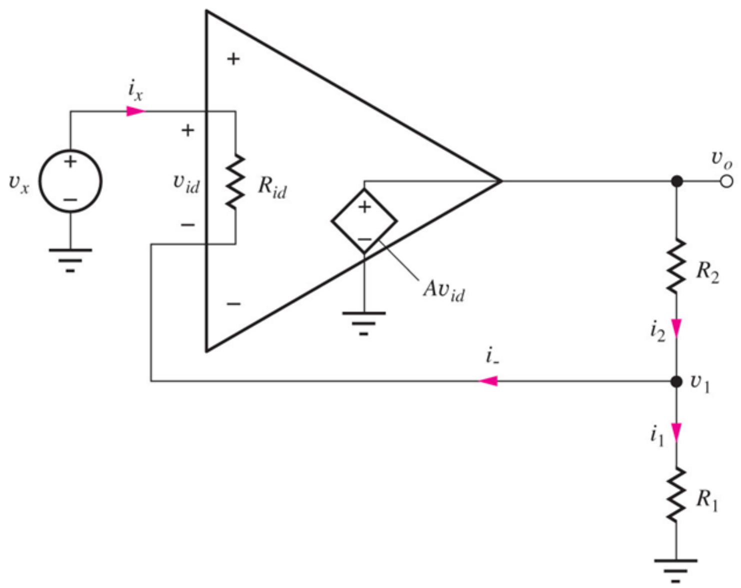


Figure 1
Rajah 1

(50 marks/*markah*)

2. Consider the circuit in Figure 2. Op amp has an open-loop gain, A_o of 90 dB, an input resistance, R_{id} of 20 kΩ, and output resistance, R_o of 1 kΩ. Assume that the op amp is driven by a signal voltage with 2-kΩ source resistance, R_S and output voltage is connected to load resistance, R_L of 1-kΩ. Feedback network is implemented with R_2 = 92 kΩ and R_1 = 10 kΩ. Hence,

Pertimbangkan litar di Rajah 2. Penguat kendalian mempunyai nilai gandaan gelung-terbuka, A_o sebanyak 90 dB, rintangan masukan, R_{id} 20 kΩ dan juga rintangan keluaran, R_o sebanyak 1 kΩ. Anggap bahawa penguat kendalian tersebut dipacu oleh isyarat voltan masukan dengan rintangan sumber, R_S bernilai 2-kΩ, dan isyarat voltan keluaran dihubungkan kepada rintangan beban, R_L 1-kΩ. Jaringan suapbalik diimplementasi menggunakan rintangan-rintangan R_2 = 92 kΩ dan R_1 = 10 kΩ. Maka,

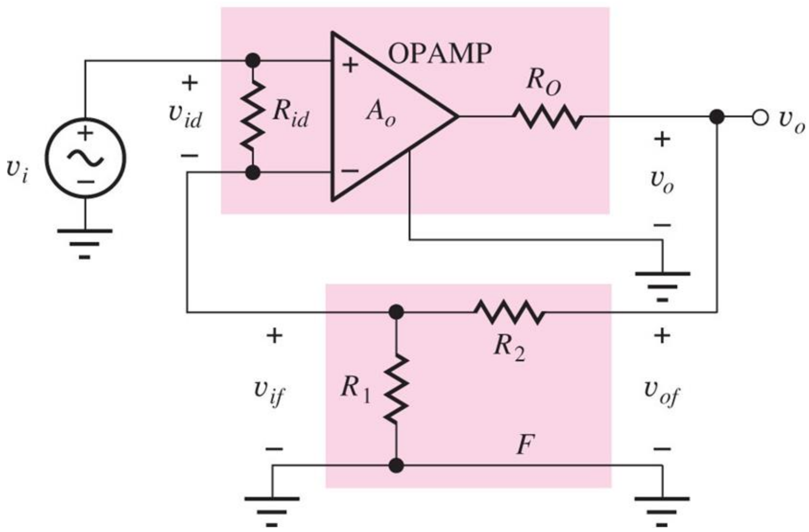


Figure 2
Rajah 2

(a) Find input resistance of the circuit, R_{in}
Dapatkan rintangan masukan litar, R_{in}

(30 marks/*markah*)

(b) Find output resistance of the circuit, R_{out}
Dapatkan rintangan keluaran litar, R_{out}

(30 marks/*markah*)

(c) Find closed loop gain of the circuit, A_v
Dapatkan gandaan gelung-tertutup bagi litar , A_v

(40 marks/*markah*)

3. (a) A silicon pnp transistor has an effective base width of 10 µm and I_C = 0.5 mA. If the emitter-base depletion capacitance is 2 pF in forward-bias region and is constant, calculate the device transition frequency, f_T. Neglect the collector-base capacitance. Diffusion coefficient of minority carrier in the base is 13 cm^2/s and thermal voltage, V_T is 26 mV.

Satu transistor silikon pnp mempunyai lebar efektif 'base' 10 µm dan I_C = 0.5 mA. Jika kapasitan pemancar-'base' ialah 2 pF dalam kawasan "forward-bias" dan nilainya malar, kirakan frekuensi transisi, f_T. Abaikan kapasitan pemungut-'base'. Pekali diffusion untuk pembawa minoriti dalam 'base' ialah 13 cm^2/s dan voltan suhu, V_T ialah 26 mV.

Given:
Diberi:

$$\tau_F = \frac{W_B^2}{2D_p}$$

(50 marks/*markah*)

(b) For the circuit in Figure 3, calculate:
Bagi litar dalam Rajah 3, kirakan:

(i) The g_m, r_π and r_0
g_m, r_π dan r_0

(30 marks/*markah*)

(ii) Voltage gain, $A_v = V_0/V_i$, if an 8 kΩ resistor is connected to node "y", node "z" is shorted to ground and a voltage source with an internal resistance of 2 kΩ is connected to node "x".

Gandaan voltan, $A_v = V_0/V_i$, jika satu perintang 8 kΩ disambungkan kepada titik "y", titik "z" dipintaskan ke tanah dan sumber voltan dengan kerintangan dalaman 2 kΩ disambungkan ke titik "x".

(20 marks/*markah*)

Given $\beta_0 = \beta_F = 100$, V_A = 100 V and V_{BE} = 0.7 V. Infinity capacitor means that at the operating frequency, the capacitor can be represented by a short.

Diberi $\beta_0 = \beta_F = 100$, V_A = 100 V dan V_{BE} = 0.7 V. Kapasitan infiniti bermaksud pada frekuensi operasi, kapasitor ini boleh diwakilkan sebagai litar pintas.

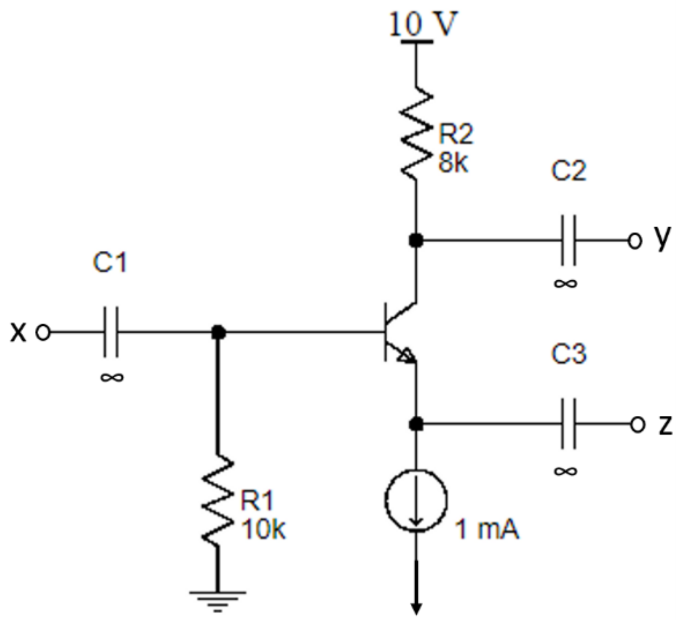


Figure 3
Rajah 3

4. (a) Draw the small signal model of the circuit configuration.
Lukiskan gambarajah isyarat kecil.

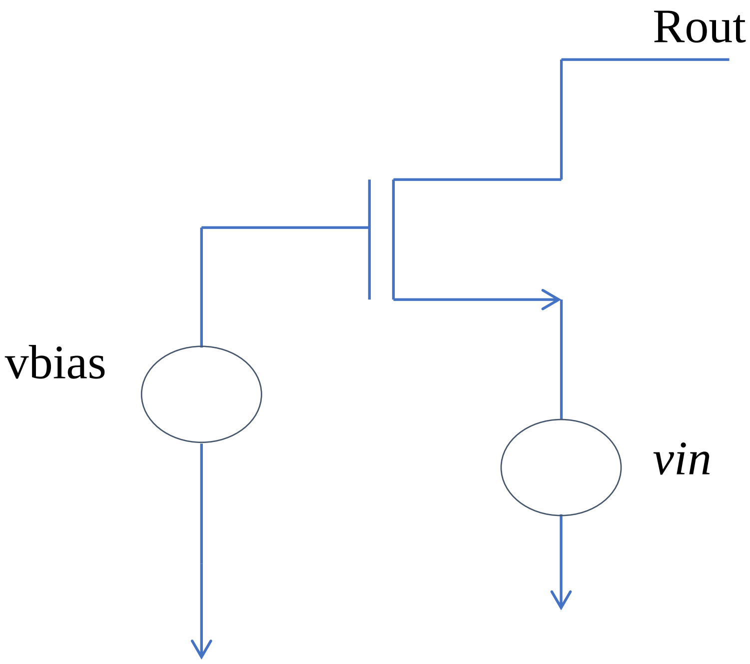
(20 marks/*markah*)

(b) Derive the transconductance gm of configuration in Figure 4.
Dapatkan gm transkonduktan konfigurasi Rajah 4.

(40 marks/*markah*)

(c) Derive the output resistance of configuration in Figure 4.
Dapatkan rintangan keluaran konfigurasi Rajah 4.

(40 marks/*markah*)



Rajah 4
Figure 4

5. (a) Derive the gain of this circuit in Figure 5.
Hasilkan persamaan gandaan untuk litar Rajah 5.

(50 marks/*markah*)

(b) Derive output resistance and transconductance gm for this configuration.
Terbitkan persamaan rintangan keluaran dan trankonduktan bagi konfigurasi ini.

(50 marks/*markah*)

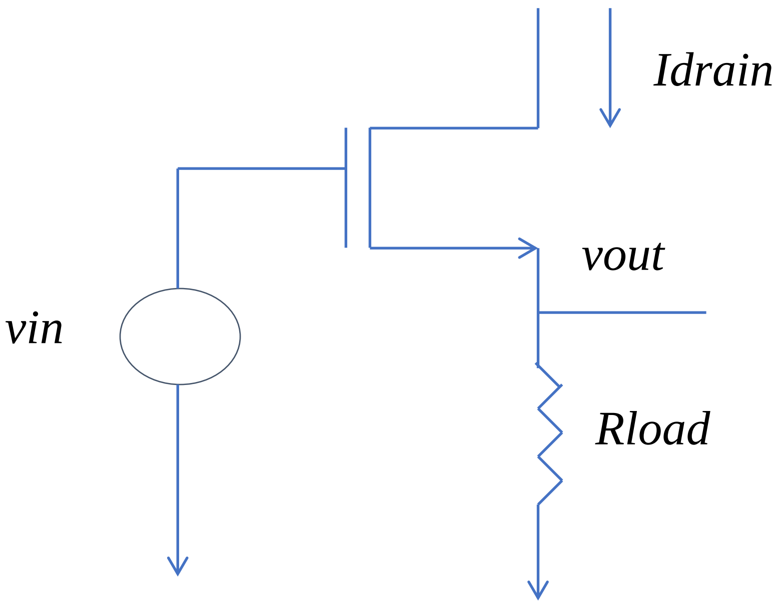


Figure 5
Rajah 5

- **oooOooo** -

Appendix A

The following are the standard resistor values available in carbon film with a 2 or 5 percent tolerance. Values are in Ohms with K = 1,000 and M = 1,000,000.

1.0	10	100	1.0K	10K	100K	1.0M	10M
1.1	11	110	1.1K	11K	110K	1.1M	11M
1.2	12	120	1.2K	12K	120K	1.2M	12M
1.3	13	130	1.3K	13K	130K	1.3M	13M
1.5	15	150	1.5K	15K	150K	1.5M	15M
1.6	16	160	1.6K	16K	160K	1.6M	16M
1.8	18	180	1.8K	18K	180K	1.8M	18M
2.0	20	200	2.0K	20K	200K	2.0M	20M
2.2	22	220	2.2K	22K	220K	2.2M	22M
2.4	24	240	2.4K	24K	240K	2.4M	
2.7	27	270	2.7K	27K	270K	2.7M	
3.0	30	300	3.0K	30K	300K	3.0M	
3.3	33	330	3.3K	33K	330K	3.3M	
3.6	36	360	3.6K	36K	360K	3.6M	
3.9	39	390	3.9K	39K	390K	3.9M	
4.3	43	430	4.3K	43K	430K	4.3M	
4.7	47	470	4.7K	47K	470K	4.7M	
5.1	51	510	5.1K	51K	510K	5.1M	
5.6	56	560	5.6K	56K	560K	5.6M	
6.2	62	620	6.2K	62K	620K	6.2M	
6.8	68	680	6.8K	68K	680K	6.8M	
7.5	75	750	7.5K	75K	750K	7.5M	
8.2	82	820	8.2K	82K	820K	8.2M	
9.1	91	910	9.1K	91K	910K	9.1M	

The following are standard capacitor values. Values below 1 uF are available with a 5 or 10 percent tolerance. Values over 1 uF are available with a 10 or 20 percent tolerance. Values are in Farads with p = pico, n = nano, u = micro, and m = milli.

1p	10p	100p	1.0n	10n	100n	1.0u	10u	100u	1.0m	10m
12p	120p	1.2n	12n	120n	1.2u					
1.5p	15p	150p	1.5n	15n	150n	1.5u	15u	150u	1.5m	15m
18p	180p	1.8n	18n	180n	1.8u					
2.2p	22p	220p	2.2n	22n	220n	2.2u	22u	220u	2.2m	22m
27p	270p	2.7n	27n	270n	2.7u					
3.3p	33p	330p	3.3n	33n	330n	3.3u	33u	330u	3.3m	33m
39p	390p	3.9n	39n	390n	3.9u					
4.7p	47p	470p	4.7n	47n	470n	4.7u	47u	470u	4.7m	47m
56p	560p	5.6n	56n	560n	5.6u					
6.8p	68p	680p	6.8n	68n	680n	6.8u	68u	680u	6.8m	68m
82p	820p	8.2n	82n	820n	8.2u					

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	$C_\mu = \frac{C_{\mu 0}}{\left(1 - \frac{V_{BC}}{\psi_{0c}}\right)^{n_c}}$
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	$g_m r_o = \frac{V_A}{V_T} = \frac{1}{\eta}$