National Exams **December 2002**

98-Elec-B5, Advanced Electronics

3 hours Duration, Closed Book

Notes:

1. If any doubt exists as to the interpretation of any question, the candidate is urged to submit, within their answer, a clear statement of any assumptions made.
2. This is a "Closed Book" Examination.
3. Candidates may use one of two calculators, the Casio or Sharp approved models.
4. Any 5 (FIVE) questions constitute a complete paper. Only the first five questions presented for evaluation will be marked.
5. All questions are worth 20 marks each.
6. Please start each question on a new page and clearly identify the question number and part number, e.g. Q4(a).
7. In schematics, ground and chassis may be assumed to be common, unless specifically stated otherwise.
8. Unless otherwise specified, assume that Op-Amps are ideal and that supply voltages are ± 15V.

Q1. [20 Marks] Filters

(a) Sketch the pole-zero diagram for a Butterworth, low-pass filter for which $n = 5$ and $\omega_0 = 1500$Hz.

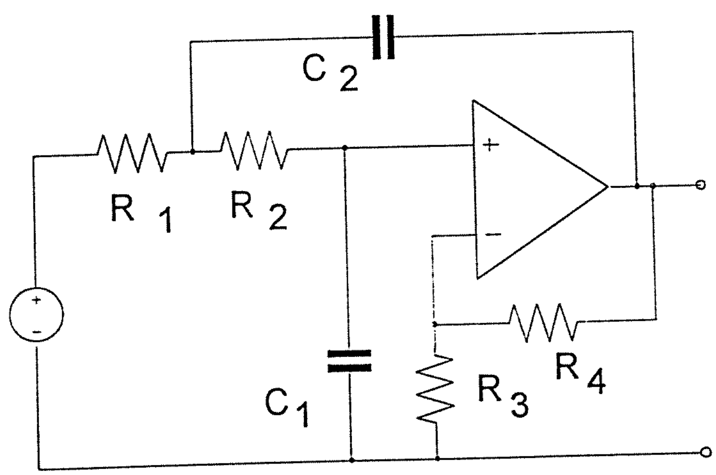
(b) For a Butterworth, Low-Pass Filter having the following specification:

Maximum attenuation for frequencies below 1500 Hz = 0.1 dB
Minimum attenuation for frequencies above 2000 Hz = 20 dB
Gain = 10 :

Determine:

(i) the number of stages required,

(ii) the component values for ONE of the Sallen-Key circuits configured as below.



Q2 [20 Marks] Modulation/demodulation

(a) Two voltages:

$$v_s = A_m \sin(\omega_m t + \psi)$$

$$v_c = A_c \sin(\omega_c t)$$

representing a modulating signal and a carrier, respectively, are applied in series to a non-linear device for which:

$$i = a + b\,v + c\,v^2$$

i) Derive an expression for the output voltage which appears across a linear resistance in series with the above device;

ii) Define this type of modulation and indicate which component(s) would be transmitted if these signals were generated by a local radio station

(b) Making use of a fully annoted sketch, describe, briefly, the operation of a balanced demodulator capable of recovering the original modulating signal from the above transmitted signal.

Q3. [20 Marks] Oscillators

An ongoing project requires an oscillator that may be tuned over three decades of frequency, in the kiloherz range. Using a switch to select the decade is acceptable. The oscillator is expected to run from a rechargeable 9v battery, to provide a sinusoidal output voltage which may be varied from zero to a maximum of 2.5v (r.m.s.), and to tolerate reasonable temperature changes.

(a) Discuss the decisions involved in the design of such an oscillator.

(b) Design such an oscillator using one, or more, operational amplifiers.

Clearly state and justify all assumptions.

Q4. [20 Marks] Power Amplfiers

(a) Design a Class-AB power amplifier that will deliver 20 watts rms into an 8 ohm loud speaker.
Justify your choice of supply voltage and biasing method.

(b) Explain, briefly, the purpose of each component in your circuit.

(c) Determine the average current drawn from the supply.

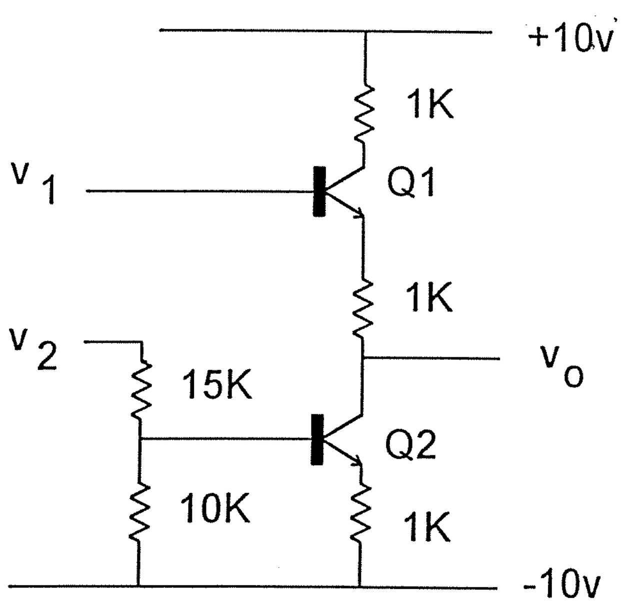
(d) Calculate the efficiency of your circuit when delivering full-rated power at 1 KHz.

Q5 [20 Marks] Amplifiers

(a) For the cascode circuit shown below, determine values for v_1 and v_2 required to produce $v_0 = (+6 + 2\sin \omega t)$ volts.

(b) Suggest an application for such a circuit.

Assume $\beta \gg 1$, $V_{be(on)} = 0.7$ v

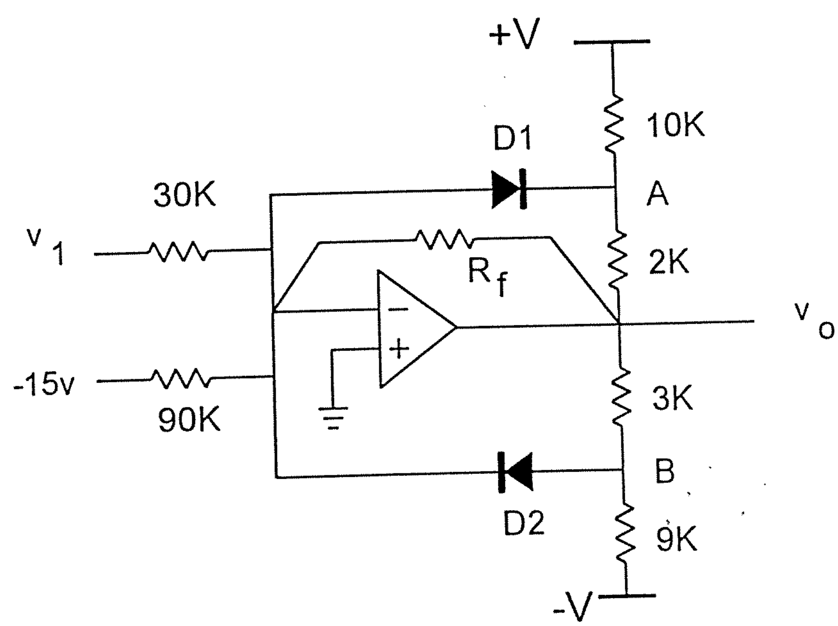


Q6 [20 Marks] Operational amplifiers - Comparators and Limiters

In the circuit below let V = 15v and assume that the op-amp and diodes are ideal.

(a) For R_f = 90KΩ, sketch the transfer characteristic (v_o/v_i) for $-V \le v_i \le +V$ and indicate all slopes and intersections.

(b) Super-impose on the transfer characteristic the effect of making $R_f = \infty$.



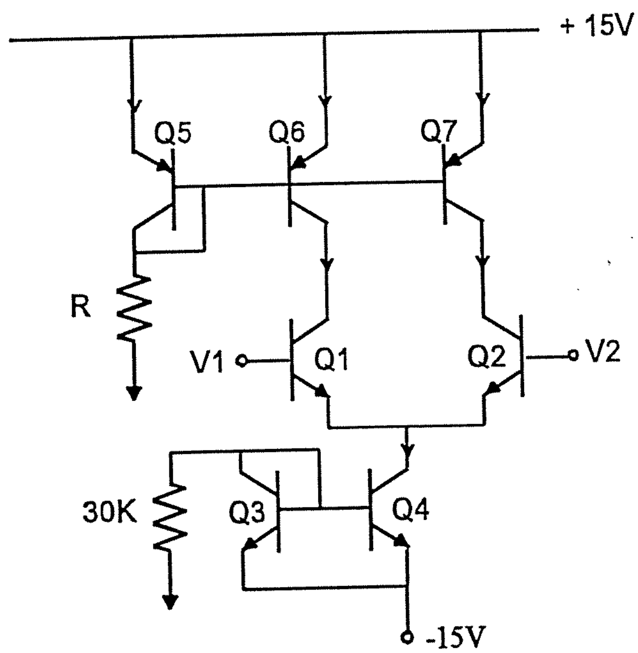
Q7 [20 Marks] Bipolar Junction Transistors

The circuit below shows an emitter-coupled pair in which Q1 and Q2 are biased by Q3 and Q4. Q6 and Q7 form the loads for Q1 and Q2 and together with Q5 form a current repeater.

For all PNP transistors $\beta_F = 100$ and $V_A = \infty$;
For all NPN transistors $\beta_F = 150$ and $V_A = \infty$.

(a) Explain, briefly, the operation of the current mirror formed by Q3 and Q4.

(b) Find a suitable value for R such that all current relationships are satisfied and justify your answer when V1 = V2.



Q8 [20 Marks] Devices

(a) Explain, briefly, why classical pn-junction diodes are not very suitable for high-frequency applications.

(b) With the aid of well annotated sketches, describe the construction and principle of operation of THREE of the following high frequency diodes:

- (i) Schottky diode
- (ii) PIN diode
- (iii) IMPATT diode
- (iv) TRAPATT diode
- (v) Gunn diode
- (vi) Varactor diode

(c) Provide a circuit diagram and explanation for a different application (other than a simple rectifier action) for each of the diodes you selected above.

Q9 [20 Marks] Multistage amplifiers

Consider an amplifier with an open-loop transfer function characterized by three widely separated poles at, say, 100kHz, 1.0 MHz and 10 MHz.

(a) Construct Bode plots for the magnitude (in dB) and phase angle (in degrees for this amplifier which has an open-loop gain of 100dB at low frequencies.

(b) Add a horizontal line to represent $20\log(1/\beta)$ on the magnitude plot such that the gain margin and phase margins are both zero.

(c) From these plots determine the phase margin when the feedback is adjusted to provide stable operation with 25dB gain margin.

(d) Explain how you could compensate this amplifier to provide stable operation with 50dB closed-loop gain.

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