THE UNIVERSITY OF WARWICK

Third Year Examinations : Summer 2011

ANALOGUE SYSTEMS DESIGN

Candidates should answer ALL 4 QUESTIONS.

Time Allowed : 3 hours.

Only calculators that conform to the list of models approved by the School of Engineering may be used in this examination.

Read carefully the instructions on the answer book and make sure that the particulars required are entered on each answer book.

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1. Give a brief qualitative description of the principles of operation of the Wien bridge oscillator circuit shown in Figure 1 below. (3 marks)

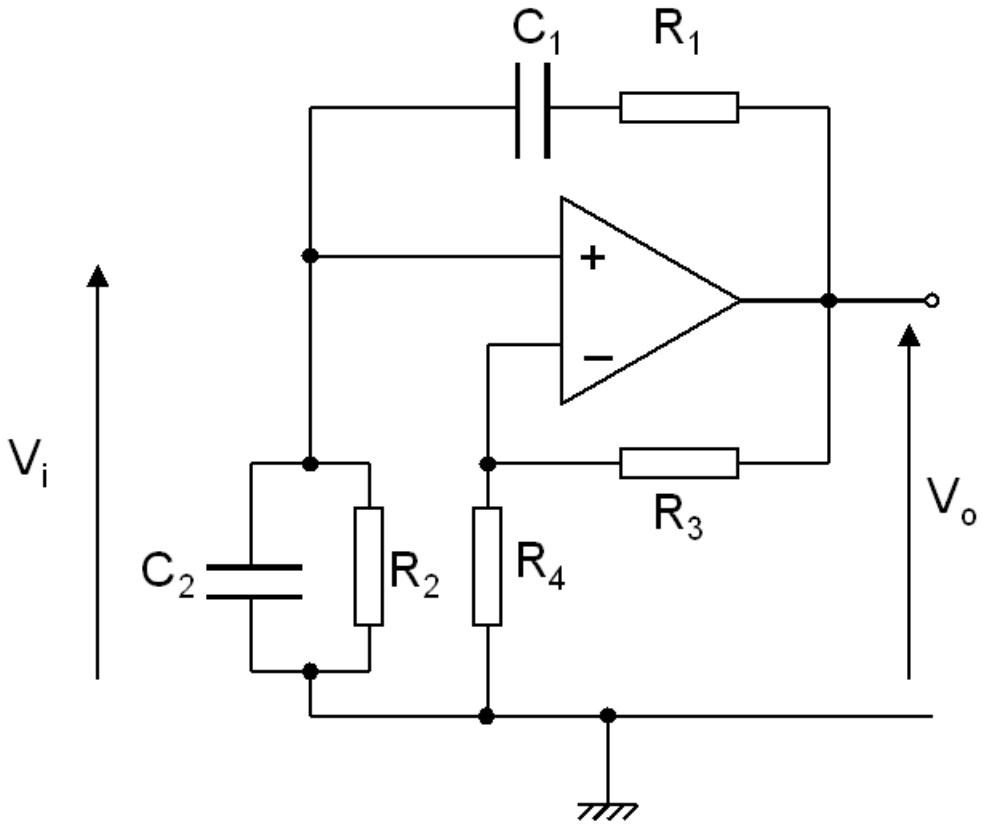

Figure 1

Re-draw the circuit schematic showing the frequency selective components only. (3 marks)

Derive the transfer function $V_o(j\omega)/V_i(j\omega)$ in terms of the components in the circuit. (6 marks)

Subject to the condition that $C_1 = C_2 = C$ and $R_1 = R_2 = R$, obtain the condition for resonance, state the resonant frequency, and deduce the op-amp gain required to maintain oscillations. (6 marks)

State the conditions necessary for oscillations to commence and to be stably maintained, giving two possible ways by which this could be achieved in practice. (7 marks)

(Total 25 marks)

2. Describe the configuration of the two-stage low-frequency amplifier shown in Figure 2. Briefly outline the merits or otherwise of using this particular arrangement. (5 marks)

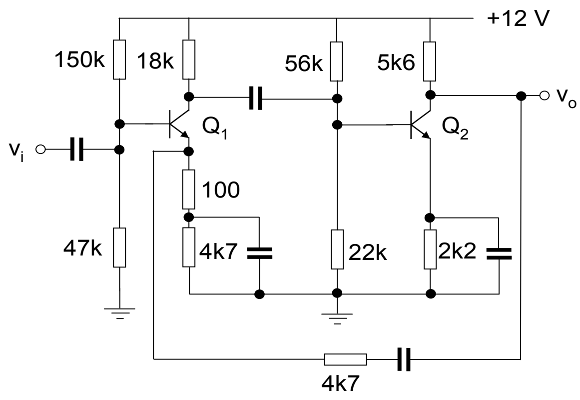

Figure 2

Assuming that $\beta = 200$ for both Q_1 and Q_2 and for the component values shown, calculate the following :

(i) the voltages at the base and emitter of Q_1 and Q_2; (2 marks)

(ii) the open loop voltage gain for Q_1 and Q_2; (6 marks)

(iii) the open loop input and output resistance of the amplifier; (4 marks)

(iv) the feedback fraction; (2 marks)

(v) the closed loop voltage gain of the amplifier; (2 marks)

(vi) the closed loop input and output resistance of the amplifier. (4 marks)

(Total 25 marks)

3. Given that the collector current of a bipolar junction transistor (BJT) can be expressed as :

$$I_C \quad = \quad k_Q A_e \exp(V_{BE}/V_T)\left(1 + \frac{V_{CE}}{V_A}\right)$$

where V_A is the Early voltage, V_T is the thermal voltage, A_e the transistor emitter area and k_Q a process dependent constant, explain how BJTs can be used to realise basic integrated circuit current mirrors.

(5 marks)

State the main advantages and disadvantages of this basic configuration. (5 marks)

Show how can this basic configuration be improved upon in the base current compensated current mirror by deriving a relationship between the reference current and the mirrored current in terms of the BJT current gain.

(5 marks)

How does the Widlar current source offer a further improvement ? Sketch a circuit schematic of the Widlar source and show that the mirrored current I_M can be expressed in terms of the reference current I_{Ref} as :

$$I_M \quad \approx \quad \frac{A_{e2}}{A_{e1}} I_{Ref} \exp(-I_M R/V_T)$$

(5 marks)

If the ratio of emitter areas is chosen such that $A_{e2}/A_{e1} = 0.1$ and $I_{Ref} = 1$ mA, calculate the value R required to set $I_M = 10$ μA.

(5 marks)

(Total 25 marks)

4. Explain the essential underlying principles of operation for each of the following :

(i) Quantised feedback analogue-to-digital converters (8 marks)

(ii) Charge balance voltage to frequency converters (8 marks)

(ii) Logarithmic and exponential amplifiers (9 marks)

Include annotated circuit diagrams and/or block schematics as appropriate in each case to illustrate your answer.

(Total 25 marks)

END