The University Of Sheffield.

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DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2012/2013 (2 hours)

EEE 204 OR: ELECTRONIC DEVICES IN CIRCUITS 2

Answer **THREE** questions. Solutions will be considered in the order in which they are presented in the answer book and **no marks will be awarded for an attempt at a fourth question.** Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

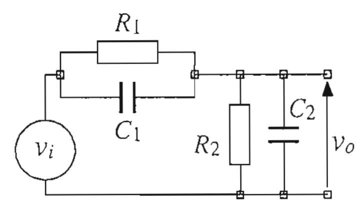

Figure 1

1 (a) (i) Write down the high frequency and low frequency gains of the circuit of figure 1 in terms of the circuit components. {3}

(ii) Show that the transfer function, v_o/v_i of the circuit is given by:

$$\frac{v_o}{v_i} = k\frac{\left(1+j\frac{f}{f_0}\right)}{\left(1+j\frac{f}{f_1}\right)},$$

where $k = \dfrac{R_2}{R_1+R_2}$, $f_0 = \dfrac{1}{2\pi C_1 R_1}$ and $f_1 = \dfrac{R_1+R_2}{2\pi\,(C_1+C_2)\,R_1R_2}$ {3}

(iii) If R_1= 9MΩ, R_2= 1MΩ, C_1= 30pF and C_2 = 150pF, sketch the v_o that you would expect to observe in response to a 500Hz, 20V peak to peak square wave input voltage. Label peak and aiming voltages and the time constant of the response. {4}

(iv) What C_1 would be necessary to remove all frequency dependent behaviour from the circuit transfer function if C_2, R_1 and R_2 had the values given in part (a) (iii)? {3}

(b) A particular design requires a non-inverting amplifier with a gain of 25 and a -3dB bandwidth of at least 3MHz. The available op-amps have a gain-bandwidth product of 50MHz.

(i) Show that a single op-amp is not capable of achieving the required performance. {2}

(ii) It is decided to meet the design requirement by using a cascade of two identical non-inverting amplifier stages based on the available op-amps. What d.c. gain is required of each stage and what will be the -3dB bandwidth of the cascade? {5}

2 (i) Show that the Sallen and Key circuit of figure 2 has a transfer function :

$$\frac{v_o}{v_i} = \frac{A}{1 + sCR\left(\frac{2}{x} + x(1-A)\right) + s^2C^2R^2}$$

where x is a constant and A is a well defined non-inverting gain. {6}

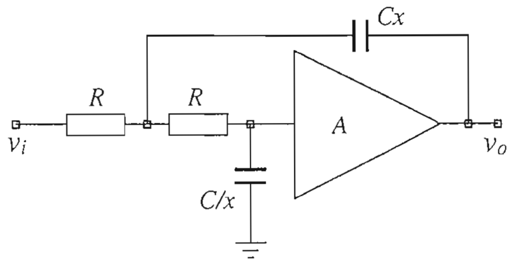

Figure 2

(ii) Draw the diagram of a circuit capable of providing the well defined non-inverting gain A. {2}

(iii) What relationship between x and A must be satisfied in order for the circuit to be stable? {3}

(iv) Find expressions for the undamped natural frequency and q factor of the transfer function given in part (**i**). {3}

(v) The circuit is to be used to realise part of a third order Butterworth low pass filter with a cut off frequency of 10kHz. All the resistors in the circuit are to be 10kΩ and the gain A is to be unity. Find the values of C and x needed in the second order section and the value of capacitance needed in the first order section of the filter. Sketch the complete circuit diagram. A normalised third order Butterworth polynomial in factored form is $(s+1)(s^2+s+1)$. {6}

The standard form of a second order, lowpass, transfer function is $\frac{v_o}{v_i} = k\frac{1}{1 + \frac{s}{\omega_o q} + \frac{s^2}{\omega_o^2}}$ where k is dimensionless.

3 (a) Figure 3 shows a network consisting of noisy resistors and noise voltage and current generators.

(i) Find the noise free resistance R_{Th} and the mean - square noise voltage v_{nTh}^2 (in terms of V^2Hz^{-1}) which form the Thevenin equivalent of the noisy network. {8}

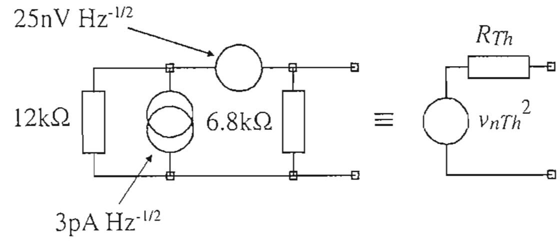

Figure 3

(ii) What noise temperature must be assigned to R_{Th} in order to account for the total output noise, v_{nTh}^2 ? {2}

(b) Define the terms "Signal to Noise Ratio" and "Noise Factor". {3}

(c) A particular low noise amplifier has an infinite input resistance, a voltage gain of 100V/V and equivalent input noise voltage and current generators of 6nV $Hz^{-1/2}$ and 0.5pA $Hz^{-1/2}$ respectively. It is fed by a source with a noisy internal (Thevenin equivalent) resistance of 10kΩ.

(i) Draw a noise equivalent circuit of the system. {3}

(ii) With an input signal amplitude of zero, the amplifier output voltage is measured using a true rms voltmeter with a noise bandwidth of 10kHz. What rms noise voltage would you expect the meter to indicate? {4}

The mean square thermal noise voltage generated by a resistor R is $4kTR$ V^2 Hz^{-1} where $k = 1.38 \times 10^{-23}$ J K^{-1}. The ambient temperature, T, is 300K throughout the question.

4 **(i)** Show that the maximum power dissipation in the output stage of an ideal class B amplifier driving a **triangular** waveshape with a peak value V_P across a resistive load, R_L, occurs when:

$$P_{DISS} = P_{LOAD} = \frac{3V_{CC}^2}{16R_L}$$

where V_{CC} is the magnitude of the positive and negative supply rails and P_{DISS} is the total output stage power dissipation. {*6*}

If R_L is 8Ω, the maximum load power required is 50W, the waveform is triangular and the output voltage can swing all the way between $+V_{CC}$ and $-V_{CC}$,

(ii) What power supply voltages, $\pm V_{CC}$, are necessary? {*2*}

(iii) Sketch the waveform of the current drawn from the positive supply when the amplifier is delivering 50W to the load, labelling times and amplitudes as appropriate. {*3*}

(iv) The output transistors, whose junction temperatures must not exceed 150°C, have a junction to case thermal resistance of 2°C W^{-1} and are both mounted on the same heatsink using insulating washers with a thermal resistance of 0.75°C W^{-1}. A regulator IC providing power for the preamplifier stages of the system is also bolted to the heatsink and dissipates a constant 5W. If the heatsink temperature must not exceed 100°C, and the worst case ambient temperature is 35°C, what is the maximum heatsink thermal resistance that can be tolerated? {*5*}

(v) The 8Ω load is replaced by a 33μF capacitor which is driven by a 1kHz triangular voltage waveform with a fundamental frequency of 1kHz and a peak value of 30V. Sketch the waveshape of the positive power supply current that you would expect to observe, taking care to label times and amplitudes on your sketch. {*4*}

For a triangular wave of peak value V_P, the rms value is $\frac{V_P}{\sqrt{3}}$ and the average value of a half wave rectified version of the waveform is $\frac{V_P}{4}$. The current through a capacitor is related to the voltage across it by $I = C\frac{dV}{dt}$.

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