The University of Sheffield
Department of Electronic and Electrical Engineering

Analogue and Digital Electronics Problem Sheet

Noise

In all questions the noise generated by a noisy resistor is $4kTR$ V^2 Hz^{-1} where $k = 1.38 \times 10^{-23}$ JK^{-1} and $T = 300$ K.

Q1 If the two resistors in the circuit of figure 1 are noise free,

(i) Find the rms noise voltage, v_{on}, in V $Hz^{-1/2}$. (19.4nV$Hz^{-1/2}$)

(ii) What is the total rms noise voltage, v_{on}, over a 20 kHz bandwidth ? (2.74μV)

(iii) If the circuit is represented by a Thevenin equivalent consisting of v_{on} and a resistance R_{Th}, find R_{Th}. (7.76 kΩ)

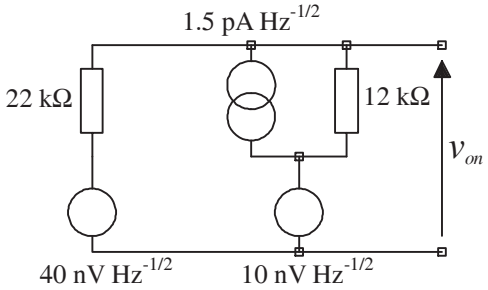

Figure 1

(iv) What is the noise temperature of the Thevenin equivalent resistance if it is assumed that this resistance is responsible for all the noise of part **(i)**? (880K)

Q2 In the circuit of figure 2, R_S is a noisy resistance of 10 kΩ, v_n is a noise source of 15 nV $Hz^{-1/2}$ and i_n is a noise source with a mean squared value of 2.25×10^{-24} A^2 Hz^{-1}. Find the rms output noise, v_{on}. (24.8 nV $Hz^{-1/2}$)

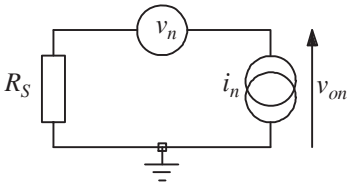

Figure 2

Q3 In the circuit of figure 3, only the 20 V source is noise free.

(i) What is the noise voltage across the diode in terms of V $Hz^{-1/2}$? (868pV$Hz^{-1/2}$)

(ii) What is the Thevenin equivalent resistance from which that noise comes ? (91Ω)

(iii) What is the effective noise temperature of the resistance calculated in part **(ii)**? (150K)

(iv) If the output is loaded by a 10 pF capacitor, what is the total rms noise voltage at the output? (14.4μV)

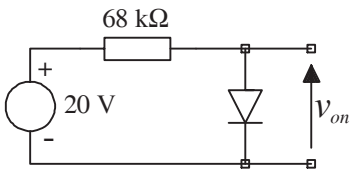

Figure 3

The noise generated by a diode is $2eI$ A^2 Hz^{-1} where $e = 1.6 \times 10^{-19}$ C. (***Hint:*** *Remember that the diode has a slope or incremental resistance* $r_d = kT/eI$ *where I is the dc bias current through the diode. This resistance will affect the noise but will not itself contribute to it*)

Q4 In the circuit of figure 4, $i_n = 6$ pA Hz$^{-1/2}$. Find the total rms noise voltage across C. (*This question involves quite a lot of careful circuit analysis so leave this it until you have done all the others.*) ()

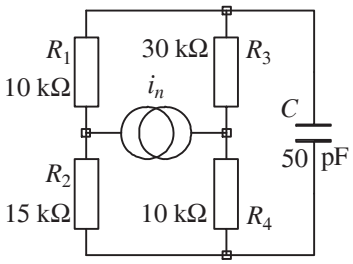

Figure 4

Q5 A particular amplifier has a noise free input resistance of 50kΩ and equivalent input noise voltage and current generators of 12 nV Hz$^{-1/2}$ and 0.6 pA Hz$^{-1/2}$ respectively. The amplifier gain is 100 V/V. The amplifier is fed from a signal source with a noisy Thevenin equivalent internal resistance of 20 kΩ.

(i) What is the output noise voltage in terms of V Hz$^{-1/2}$? (1.43μVHz$^{-1/2}$)

(ii) What is the signal to noise ratio at the amplifier output if the input signal level is 50 μV rms and the amplifier noise bandwidth is 10 kHz? (402 or 26 dB)

(iii) What is the noise factor of the amplifier? (1.87)

Q6 Your boss asks you to characterise the noise performance of a new amplifier with infinite input resistance and a gain of 50 V/V by using two equivalent input noise generators, v_n and i_n. When you connect a true rms voltmeter with a noise bandwidth of 5 kHz to the amplifier output you find that when the input is short circuited to ground the meter reads 30 μV and when the input is connected to ground via a 3 kΩ resistor, the meter reads 50 μV.

(i) Draw the noise equivalent circuit of the whole measurement system.

(ii) Calculate the values of v_n and i_n? (8.49 nV Hz$^{-1/2}$, 2.95 pA Hz$^{-1/2}$)

Q7 A wideband amplifier in a matched 50 Ω system is made from two thin film amplifier modules with gains of 25 dB and 15 dB and noise figures of 4.50 dB and 7.00 dB respectively such that the overall amplifier bandwidth, Δf, is 1000 MHz.

(i) What is the gain of the series combination? (40dB)

(ii) What is the noise factor of each amplifier module? (2.82 and 5.01)

(iii) What is the noise figure of the combination if the higher gain module is at the input end of the amplifier? (4.53dB)

(iv) What is the total added noise power delivered to the load? (76.2nW)

(v) What is the signal to noise ratio at the amplifier output if the input signal power is 10 pW? (-0.7dB)

(vi) What is the effective noise temperature of the 50 Ω source resistance? (851K)

The maximum available noise power is $kT\Delta f$ W where Δf is as defined in the question. This question uses the notation (noise figure) = 10 log (noise factor).