

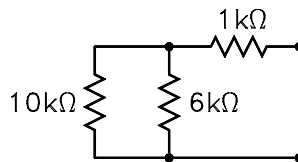
ECE 6416 Assignment 1

1. Let $v_n(t)$ be a random voltage that has a normal or gaussian probability density function with a mean value of zero and a standard deviation or mean-square of v_{rms} . In a 24 h period, the total time that the waveform exceeds a value v_1 can be estimated as 24 h multiplied by the probability that $|v_n(t)| > v_1$. Calculate the time that (a) $|v_n(t)| > 3v_{rms}$ [about 4 min], (b) $|v_n(t)| > 4v_{rms}$ [about 5 s], and (c) $|v_n(t)| > 6v_{rms}$ [about 0.2 ms].
2. Two resistors R_1 and R_2 are connected in parallel. The two resistors are in thermal equilibrium.

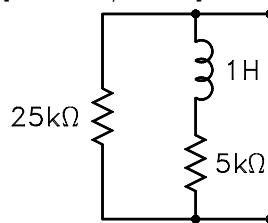
- (a) Suppose that only R_1 generates thermal noise and R_2 is noiseless, show that the average thermal noise power delivered by R_1 to R_2 in the band Δf is given by

$$P_{12} = \frac{4kTR_1R_2\Delta f}{(R_1 + R_2)^2}$$

- (b) Suppose that only R_2 generates thermal noise and R_1 is noiseless, show that the average thermal noise power P_{21} delivered by R_2 to R_1 in the band Δf is given by the same expression obtained above.
 - (c) Note that $P_{12} = P_{21}$. If the two answers were not the same, could the two resistors be in thermal equilibrium? How would the temperatures of the individual resistors vary with time if $P_{12} > P_{21}$?
3. Calculate the thermal spot noise voltage in $V/\sqrt{\text{Hz}}$ at the standard temperature across the terminals of the circuit [$v_{rms} = 8.72 \text{ nV}/\sqrt{\text{Hz}}$]



4. Calculate the spot noise voltage at the output of the circuit at the frequency $f = 1.5 \text{ kHz}$. Assume $T = T_0 = 290 \text{ K}$. [$9.83 \text{ nV}/\sqrt{\text{Hz}}$]



5. A $1 \text{ M}\Omega$ resistor has a dc voltage across it of 4 V . At the frequency $f = 100 \text{ Hz}$, the spot noise voltage across the resistor is $v_n/\sqrt{\Delta f} = 400 \text{ nV}/\sqrt{\text{Hz}}$.

- (a) Show the flicker noise coefficient is $K_f = 9 \times 10^{-13}$.

(b) Show that the noise index is $NI = 3.17$ dB.

(c) The mean-square short-circuit noise current generated by the resistor is given by

$$i_n^2 = \frac{4kT\Delta f}{R} + \frac{K_f I_{DC}^2 \Delta f}{f}$$

Show that the flicker noise corner frequency is $f_{flk} = 900$ Hz.

6. A 100 mH lossy inductor has a measured impedance magnitude of $8\text{ k}\Omega$ at the frequency $f = 10\text{ kHz}$. Show that the open-circuit thermal spot noise voltage generated by the inductor at 10 kHz is $v_t/\sqrt{\Delta f} = 8.9\text{ nV}/\sqrt{\text{Hz}}$. Note that $|Z|^2 = R^2 + (\omega L)^2$ for the inductor.

7. If the diode generates only shot noise and the resistor generates only thermal noise, solve for the ac rms noise output voltage over the band from 1 kHz to 3.5 kHz. The diode is modeled as a shot noise current source in parallel with the diode small-signal resistance given by $r_d = \eta V_T / I_D$, where η is the emission coefficient or ideality factor and I_D is the dc current in the diode. Assume $\eta = 2$ and $V_T = 25\text{ mV}$. [$v_{rms} = 23.9\text{ nV}$]

