System-Level Problems

Conceptual Problems

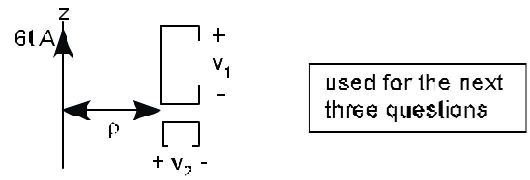

Fig. P10.1

1. (***T/F***) For t > 0, $v_1 < 0$ and $v_2 > 0$.
2. (***T/F***) For t > 0, the magnitudes of v_1 and v_2 grow larger with time.
3. (***T/F***) The magnitudes of v_1 and v_2 are independent of ρ. *Why or why not?*

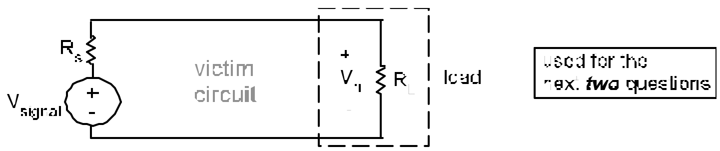

Fig. P10.2

4. (***T/F***) Reducing R_s will make noise voltage due to electric field coupling lower and will have no effect to noise voltage due to magnetic field coupling.
5. (***T/F***) Placing twists in the wires connecting the source to R_L will lower noise due to magnetic field coupling.
6. (***T/F***) Other factors being equal, noise due to electric field coupling is reduced as the impedance level of the victim circuit is reduced. *Why or why not?*
7. (***T/F***) Using twisted-pair wires is an effective method of reducing noise due to magnetic field coupling.

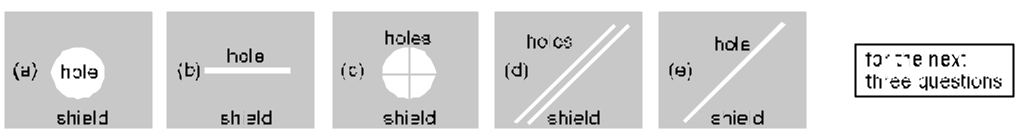

Fig. P10.3

8. (***multiple choice***) The five shields above are identical apart from their apertures. Which shield has the lowest shielding effectiveness?
9. (***multiple choice***) Which shield has the highest shielding effectiveness?
10. (***multiple choice***) Which shield has the 3rd highest shielding effectiveness? *Fully justify your answer.*
11. (***T/F***) Using twisted pair wires is an effective method of reducing noise due to magnetic field coupling.
12. (***T/F***) Using an electrostatic shield is an effective method of reducing noise due to electric field coupling.
13. (***T/F***) Other factors being equal, noise due to electric field coupling and magnetic field coupling increases as frequency increases. *Why or why not?*

14. (***T/F***) A noise voltage, f = 10^8 Hz, is 2 V with no shield. A copper shield, 2mm thick, with one 0.25 cm circular hole, is placed around the victim circuit. The noise voltage is reduced to less than 0.175 mV. *Why or why not?*

15. (***T/F***) For a signal ranging from 1 to 5 volts, a 4 bit analog-to-digital conversion would involve a maximum quantization error of 0.25 V.

16. (***T/F***) If the number of bits in an analog-to-digital conversion were doubled, the maximum quantization error would be halved.

17. (***T/F***) $101_2 + 1001_2 = 14_{10}$.

18. (***T/F***) $144_{10} = 10010000_2$.

19. (***T/F***) ASCII has more characters than does Unicode.

20. (***T/F***) In designing an electromagnetic shield with apertures, it does not matter whether the shield has four square apertures with sides of ½" or one square aperture with sides of 1" since the total area in the two cases are equal.

Workout Problems

1. For a given cantilever load cell has a linear force strain relation, $\varepsilon = (10^{-5}\ N^{-1})\ F$, where ε is the strain and F is the force in newtons. Four metallic strain gages (strain gage factor = 2) are placed on the load cell as shown below. Take V_s to be 10 V.

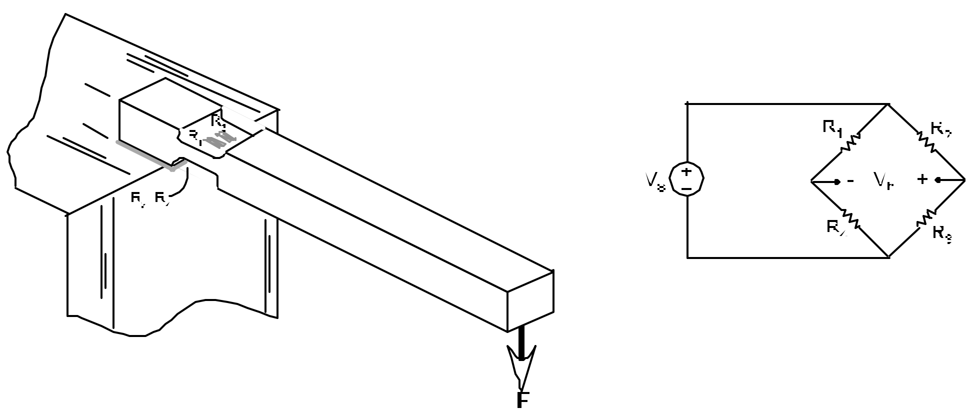

Fig. P10.4

Using this cantilever beam load cell, design a force transducer with a voltage output that satisfies the following design conditions.

i) The bridge voltage is brought to the transducer electronics via shielded twisted pair cable. Show drain wire connection.

ii) The bridge voltage, V_b, is first buffered (use a voltage follower circuit) prior to further signal conditioning.

iii) The buffered bridge voltage is filtered by a high-pass filter with a corner frequency of 100 Hz.

iv) Amplify the filtered signal so that the strain gage has a DC force-voltage relationship of V = F, where V is in volts and F is in newtons.

2. Design an over temperature alarm system using a thermocouple. Assume the temperature at which the alarm sounds is 1200 °C. The circuit should provide a zero volt output for T < 1200 °C and should provide a non-zero volt output for T $\geq$ 1200 °C. The temperature is sufficiently high that a reference junction is not needed.

   i) The thermocouple signal should be brought to the transducer electronics via shielded twisted pair cable. Show drain wire connection.

   ii) The thermocouple signal should first be buffered (use a voltage follower circuit) prior to further signal conditioning.

   iii) Filter the buffered signal using a high-pass filter with a corner frequency of 10 Hz.

   iv) Amplify the filtered signal so that the voltage at T = 1200 °C is 3 V.

   v) Use a comparator to compare the TC signal to 3 V. (assume a 3 V DC signal is available for use.)

3. A measurement system has been found, through experiment, to have the following equation of motion.

$$v'_{measured} + 2000 v_{measured} = 20 \times 10^3 v_{actual}$$

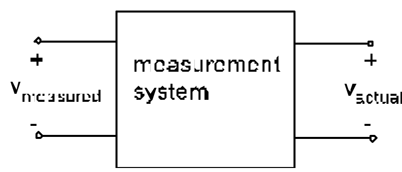

Fig. P10.5

   i) Determine the Static Gain and Time Constant.

   ii) Write the transfer function, in the s domain, for $v_{measured}$ as output and $v(t)_{actual}$ as input.

   iii) Find $v(t)_{actual}$, in steady-state, given $v(t)_{measured}$ = 6 + 14 cos(1500t – 16.9°) V.

4. Below is a sketch of the cable specified for the Universal Serial Bus (USB). USB cable is designed for high-speed data transfer and is fairly immune from electric and magnetic field coupling. It is also fairly immune to interference from common mode noise.

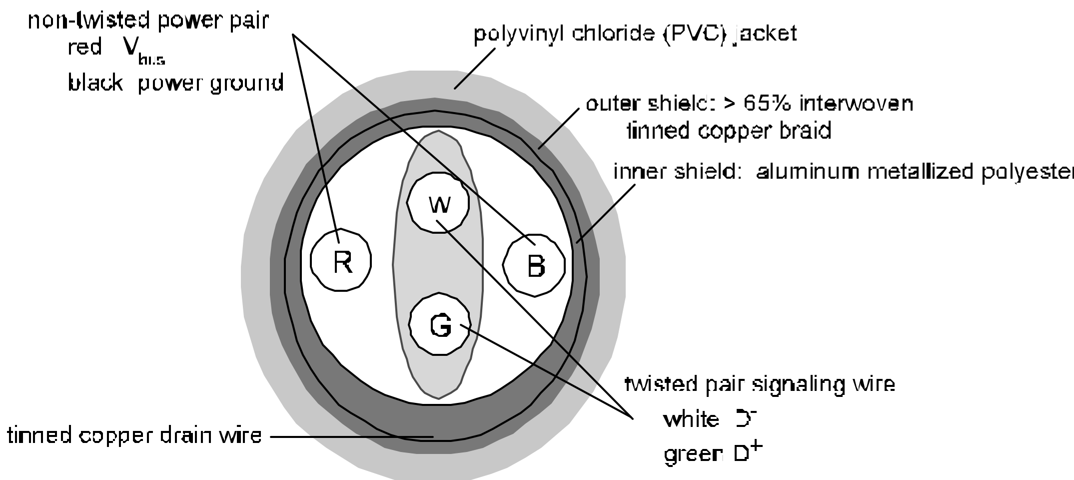

Fig. P10.6

i) What design feature helps make USB more immune to electric field coupling?

ii) What design feature helps make USB more immune to magnetic field coupling?

iii) What design feature helps make USB more immune to common mode coupling?

5. A set of holes to allow airflow for cooling is laid out on an aluminum panel as shown.
Each hole is ¼ inch in diameter. Determine the thickness of the panel needed for the holes to achieve a net 65 dB of shielding effectiveness at a frequency of 200 MHz.

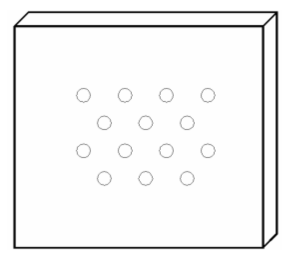

Fig. P10.7

6. The data receiver circuit for a computer has been laid out on a printed circuit card using traces 6 cm long that are spaced 2 cm apart. The circuit card assembly has been enclosed in a 2-mm thick shield whose shielding effectiveness is determined by a rectangular slot that is 12cm x 1mm. Compute the maximum voltage level received by the circuit when the computer is subjected to a magnetic field at 27 MHz having a peak amplitude of 10^{-4} Webers/m^2.

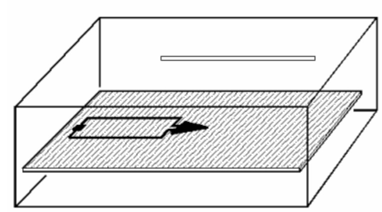

Fig. P10.8

7. Clearly discuss ways to mitigate electric-field coupling.

8. Clearly describe ways to mitigate magnetic-field coupling.

9. The circuit below depicts electric coupling into a victim circuit.

i) *Derive* an expression for the noise voltage, V_n, coupled into the victim circuit.

ii) Assume that $(R_L+R_S)>>sR_LR_S(C_L+C)$ and that $R_L>>Rs$

Is V_n dependent on R_S? If so, does it increase or decrease with R_S?
Is V_n dependent on C? If so, does it increase or decrease with C?
Is V_n dependent on ω? If so, does it increase or decrease with ω?
Is V_n dependent on R? If so, does it increase or decrease with R?
Is V_n dependent on V? If so, does it increase or decrease with V?
Is V_n dependent on V_{signal}? If so, does it increase or decrease with V_{signal}?

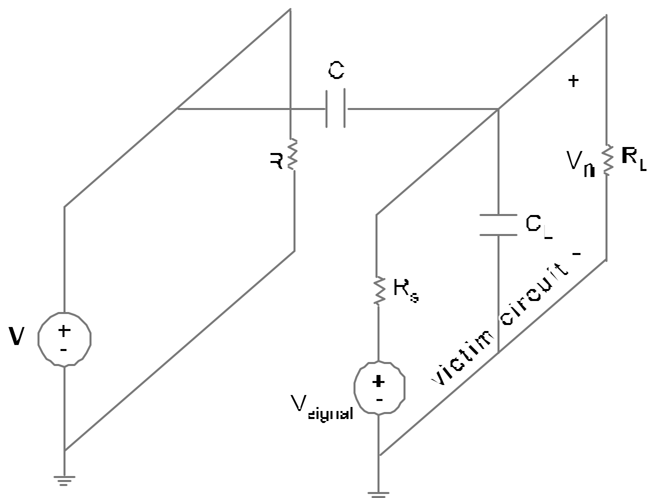

Fig. P10.9

10. In the system below, electric field coupling (inside the shield) and magnetic field coupling (from outside the shield) introduce noise across the load resistor R_L.

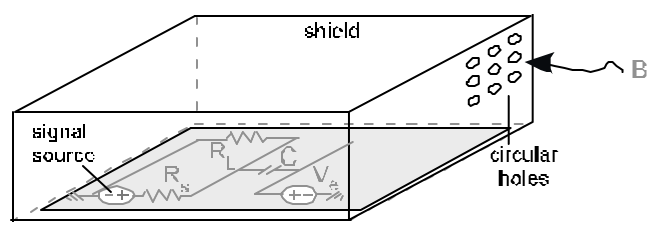

Fig. P10.10

i) *Electric field coupling*: For R_s = 300 Ω, R_L = 300 Ω, V_e = 10 V and C = 1 pF, compute the magnitude of the noise introduced across R_L due to electric field coupling if the frequency of V_e is 100 MHz.

ii) *Shielding*: Given the diameter of each hole is 0.2 cm, determine the shield thickness necessary to achieve 20 dB of shielding effectiveness. The external magnetic field's frequency is 10 GHz.

iii) *Magnetic field coupling*: Given the external magnetic field, at 10 GHz, has a magnetic flux density of 10^{-10} Wb/m^2 (outside the shield). What is the maximum loop area if the noise due to magnetic field coupling is to be less than 100 μV?

Assume 20dB shielding effectiveness is available from the shield and assume worse case orientation.

11. Extend the discussion about positional number systems to a base-16, or hexadecimal number system. There would be 15 digits in a base-16 positional number system. Let's take these as 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, and E.

    i) Represent 718_{10} in hexadecimal.

    ii) Represent $7C_{16}$ in decimal.

    iii) Represent $7C_{16}$ in binary.

    iv) Represent 1011100110_2 in hexadecimal.

12. i) Identify the function and purpose of each control character in ASCII—there are 32 of them. To obtain sufficient information regarding the ASCII control characters, use your library and/or the Internet to obtain specific details on the function and purpose of each control character.

    ii) Give the binary representation for each ASCII control character.