PROBLEMS

1.1 Find the independent nonlinearity, as defined in Figure 1.4(b), for the following set of inputs and outputs from a nearly linear system. Instrument was designed for an output equal to twice the input. Full scale is 20.

Inputs	0.50	1.50	2.00	5.00	10.00
Outputs	0.90	3.05	4.00	9.90	20.50

1.2 Find the correlation coefficient r for the set of five inputs and outputs given in Problem 1.1.

1.3 Derive the operational transfer function and the sinusoidal transfer function for an RC high-pass filter. Plot the step response and the complete frequency response (magnitude and phase).

1.4 A first-order low-pass instrument must measure hummingbird wing displacements (assume sinusoidal) with frequency content up to 100 Hz with an amplitude inaccuracy of less than 5%. What is the maximal allowable time constant for the instrument? What is the phase angle at 50 Hz and at 100 Hz?

1 차 로우 패스 악기는 진폭 부정확도가 5 % 미만인 주파수 성분이 100Hz 인 벌새의 날갯짓 변위 (정현파를 가정)를 측정해야합니다. 계측기의 최대 허용 시정 수는 얼마입니까? 50Hz와 100Hz의 위상 각은 무엇입니까?

1.5 A mercury thermometer has a cylindrical capillary tube with an internal diameter of 0.2 mm. If the volume of the thermometer and that of the bulb are not affected by temperature, what volume must the bulb have if a sensitivity of 2 mm/°C is to be obtained? Assume operation near 24 °C. Assume that the stem volume is negligible compared with the bulb internal volume. Differential expansion coefficient of Hg $= 1.82 \times 10^{-4}$ ml/(ml · °C).

1.6 For the spring scale shown in Figure 1.7(a), find the transfer function when the mass is negligible.

1.7 Find the time constant from the following differential equation, given that x is the input, y is the output, and a through h are constants.

$$a\frac{dy}{dt} + bx + c + hy = e\frac{dy}{dt} + fx + g$$

1.8 A low-pass first-order instrument has a time constant of 20 ms. Find the frequency, in hertz, of the input at which the output will be 93% of the dc output. Find the phase angle at this frequency.

저역 1 차 계측기는 20 ms의 시간 상수를 가집니다. 출력이 DC의 93 %가 될 입력의 주파수(Hz)를 찾으시오. 이 주파수에서 위상 각을 찾으시오.

1.9 A second-order instrument has a damping ratio of 0.4 and an undamped natural frequency of 85 Hz. Sketch the step response, and give numerical values for the amplitude and time of the first two positive maxima. Assume that the input goes from 0 to 1 and that the static sensitivity is 10.

1.10 Consider an underdamped second-order system with step response as shown in Figure 1.7(c). A different way to define logarithmic decrement is

$$\Gamma = \ln \frac{y_n}{y_{n+1}}$$

Figure 2.21(d) shows several results of this type of calculation. One of the examples shown is an efficient system capable of making measurements in the dark without stimulating the eye. Such a device can be used for tracking eye movements. It can be formed from a tungsten source, a Kodak 87 Wratten filter, and a silicon sensor. If GaAs provides enough output, it can replace both the tungsten source and the Kodak 87 Wratten filter (Borah, 2006).

PROBLEMS

2.1 For Figure P2.1, plot the ratio of the output voltage to the input voltage v_o/v_i as a function of the displacement x_i of a potentiometer with a total displacement x_t for ranges of R_m, the input resistance of the meter. Show that the maximal error occurs in the neighborhood of $x_i/x_t = 0.67$. What is the value of this maximal error?

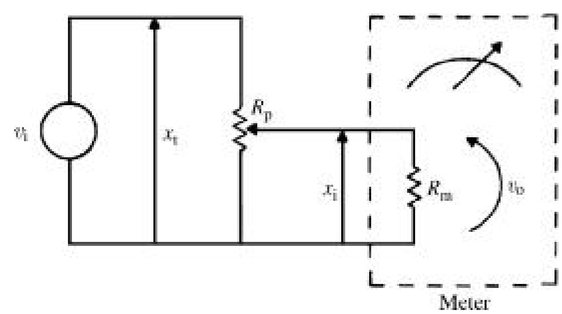

Figure P2.1

2.2 The practical limitation for wire spacing in potentiometer construction is between 20 and 40 turns/mm. Find the resolution limitation for a translational and a rotational potentiometer. Propose a way to increase the resolution of a rotational potentiometer.

2.3 Discuss some of the possible problems involved in elastic-resistance strain-gage sensors and their solutions.

2.4 The electromotive force E for a thermocouple is given by (2.21). Calculate and plot E for conditions in which the reference source is at 0 °C and temperature varies from 0 °C to 50 °C. The thermocouple material is copper constantan with $a = 38.7\ \mu V/°C$ and $b = 0.082\ \mu V/°C^2$. How significant is the second term in your calculations? Note that these calculated curves are not exactly satisfied in the practical situation. Thus an experimental calibration must be measured over the range of interest.

2.5 Using the results of Problem 2.4, calculate the sensitivity α at 37 °C for the copper–constantan thermocouple.

식 2.21에서 열전쌍에 대한 전자력은 E로 나타냅니다. 기준 원천이 0이고 온도가 약한 0에서 약한 50으로 변하는 조건에 대해 E를 계산하고 그려라. 열전쌍 물질은 a = 38.7, b = 0.082 인 구리 합금이다. 계산에서 두번째 변수는 얼마나 중요한가?
이 계산 된 곡선은 실제 상황에서 정확하게 만족되지 않습니다. 따라서 실험 교정은 관심 범위에 대해 측정해야합니다.

그림2.6(c)에 표시된 LVDT의 코어가 정상 범위를 벗어남에 따라 전압 c-e, d-e, c-d를 스케치합니다.

2.6 Calculate the value of the thermistor temperature coefficient α for $T = 300\,\mathrm{K}$ and $b = 4000\,\mathrm{K}$.

2.7 For the LVDT shown in Figure 2.6(c), sketch the voltages c–e, d–e, and c–d as the core is displaced through its normal range.

2.8 For Example 2.1, what size shunting capacitor should be added to extend the low-corner frequency to 0.05 Hz, as is required to detect pulse waveforms? How is the sensitivity changed?

예 2.1의 경우 펄스 파형을 감지하는 데 필요한 것처럼 낮은 코너 주파수를 0.05Hz까지 확장하기 위해 어떤 크기의 분로 커패시터(컨덴서, 용량체)를 추가해야합니까? 민감도는 어떻게 변경됩니까?

2.9 Design a charge amplifier for a piezoelectric sensor that has 500 pF capacitance. It should pass frequencies from 0.05 to 100 Hz so that it can detect carotid pulses, and it should not drift into saturation.

2.10 Sketch typical thermistor v–i characteristics with and without a heat sink. Explain why there is a difference.

2.11 Calculate and sketch a curve for the radiant output of the skin at 300 K at 2000, 5000, 10,000, and 20,000 nm.

2.12 Sketch an optical system using curved mirrors instead of lenses that could replace the system shown in Figure 2.20(b).

2.13 Sketch the circuit for a photo Darlington transistor, which is two cascaded emitter–follower transistors. Estimate its linearity and response time.

2.14 For the solar cell shown in Figure 2.25, what value load resistor would receive the maximal power?

2.15 For the photomultiplier shown in Figure 2.24, when R_L is high enough for adequate sensitivity, the stray capacity–R_L product produces a time constant that is too long. Design a circuit that is 10 times faster and has no loss in sensitivity.

2.16 For Figure 2.21(d), plot the relative combination product for GaP, HbO, CdS.

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