Specialized Subjects

9:00-11:30, Tuesday, August 20, 2013

Instructions

1. Do not open this booklet before the examination begins.

2. This booklet contains 5 problems. The number of pages is five excluding this cover sheet and blank pages. If you find missing or badly printed pages, ask the proctor for exchange.

3. Answer three problems. You can select any three out of the five. Your answer to each problem should be written on a separate sheet. You may use the reverse side of the sheet if necessary.

4. Fill the top parts of your three answer sheets as instructed below. Before submitting your answer sheets, make sure that the top parts are correctly filled.

<div style="text-align:center">

専　門　科　目

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| 第　　　問		受験番号 □□□
↑ Write the problem No.		↑ Write the Examinee No.

5. Submit all the three answer sheets with the examinee number and the problem number, even if your answer is blank.

6. Answer either in Japanese or English.

7. This booklet and the scratch paper must be returned at the end of the examination.

8. This English translation is supplemental and provided for convenience of applicants. The Japanese version is the formal one.

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Problem 1

Answer the following questions.

(1) Fig. 1 shows a circuit consisting of an operational amplifier and two resistors whose resistances are R_1 and R_2, respectively. Calculate the relationship between the input voltage V_{IN} and the output voltage V_{OUT}. Here, you can assume that the voltage gain of the operational amplifier is A and the other characteristics are ideal.

(2) What would happen to the input-output characteristics of the circuit in Question (1) if we cannot assume the ideal characteristics of the input impedance, the input offset voltage, and the frequency response, respectively?

(3) Design a circuit which satisfies $V_{OUT} = V_{IN}$ by using an ideal operational amplifier (such a circuit is called a voltage follower). And, give two cases where the voltage follower is used.

(4) Fig. 2 shows a sample and hold circuit consisting of a switch, a capacitor, and a voltage follower. An ideal sample and hold circuit captures the input voltage when the switch is disconnected and holds its value for a certain period of time. Discuss what kind of problems happen when an electronic switch such as a transistor is used and when a mechanical switch such as a relay or a slide switch is used, respectively.

(5) Operational amplifiers are often used for active filters. Discuss advantages and disadvantages of active filters using operational amplifiers as compared to passive filters that use only passive devices.

Fig. 1   Fig. 2
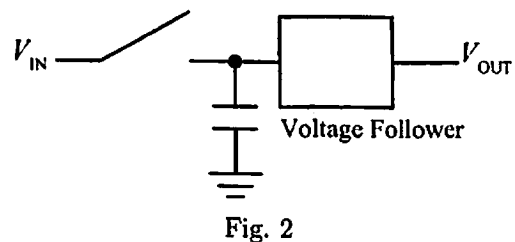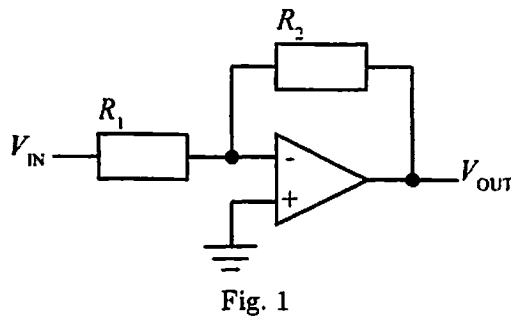
Problem 2

Answer the following questions on virtual memory.

(1) Locality of reference can be divided into temporal locality and spatial locality. Explain these two types of locality.

(2) Explain what a page table is.

(3) Explain what a Translation Lookaside Buffer (TLB) is, and how a TLB miss is related to the page table.

(4) Suppose a page fault occurs during the execution of a load instruction. Explain the process from the address calculation of the instruction until the restart of the instruction after the page fault handling.

(5) Some processors handle a TLB miss by hardware. On the other hand, it is exceptional to handle a page fault only by hardware. Discuss the reason for such a difference.

Problem 3

The sequence that is defined by $f(0) = 0$, $f(1) = 1$, and the recurrence relation
$f(n) = f(n-1) + f(n-2)$ $(n > 1)$ is called the Fibonacci sequence. Answer the following
questions on this sequence.

(1) Give a pseudo-code program to calculate $f(n)$ using recursive calls according to the recurrence relation.

(2) Give another pseudo-code program to calculate $f(n)$ from the recurrence relation without using recursive calls.

(3) Assume that 64-bit integers are used. Explain the drawbacks of each of the methods described in Questions (1) and (2).

(4) The closed-form solution of the Fibonacci sequence is

$$f(n) = \frac{1}{\sqrt{5}}\left(\left(\frac{1+\sqrt{5}}{2}\right)^n - \left(\frac{1-\sqrt{5}}{2}\right)^n\right).$$

Explain the merits and drawbacks of the calculation using this form with floating point numbers, as compared to the method described in Question (2).

Problem 4

Answer the following questions on a baseband signal $m(t)$ of bandwidth B [Hz], whose Fourier transform $M(f)$ is shown in Fig. 1. Assume ideal radio wave propagation and no multipath between the sender and the receiver. You may use the following trigonometry formula

$$\cos A \cos B = \frac{1}{2}(\cos(A+B) + \cos(A-B)).$$

(1) Using amplitude modulation, a carrier $\cos(2\pi f_C t)$ with a frequency $f_C > B$ [Hz] is modulated by $m(t)$. Show the Fourier transform $X(f)$ of the modulated radio wave signal $x(t) = m(t)\cos(2\pi f_C t)$.

(2) Let $m(t) = M$ where M is a constant. Assume the modulated signal $x(t)$ is received at a distance of z [m] from the sender. Show the received signal $y(t)$ using c [m/sec] as the propagation velocity of the radio wave. Ignore the signal attenuation due to propagation.

(3) When the sender is approaching the receiver at a constant speed of v [m/sec] ($v < c$) as shown in Fig. 2, show the observed carrier frequency f [Hz] by the receiver, where the sender was initially z_0 [m] apart from the receiver.

(4) Derive the received signal $y(t)$ when $m(t) = \cos(2\pi p t)$ in Question (3). Expand products of cosines to sums of cosines.

(5) The receiver demodulates the received signal $y(t)$ in Question (4) using synchronous detection by $\cos(2\pi f t)$ since the carrier frequency of the received signal $y(t)$ can be estimated. Derive the obtained baseband signal $m_R(t)$ and explain the effect on its amplitude, frequency and phase.

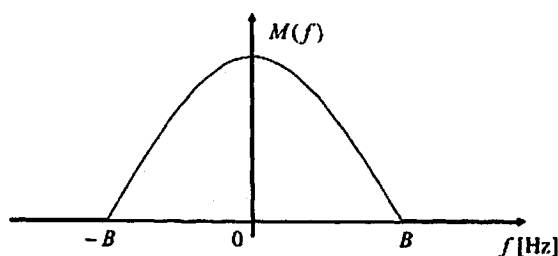(6) Derive the condition required to obtain the baseband signal $m_R(t)$ nearly proportional to the original.

M(f) graph with -B, 0, B on f [Hz] axis

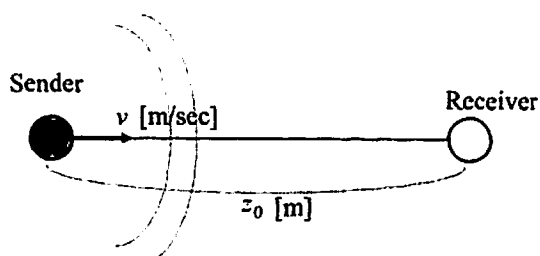Fig. 1

Sender, v [m/sec], Receiver, z_0 [m]

Fig. 2

Problem 5

Answer the following questions about discrete signal processing.

(1) Show the definition of the Z-transform $X(z)$ of a discrete signal $x(n)$ where z is a complex number. Note that the discrete signal $x(n)$ is zero for $n < 0$.

(2) Suppose that the discrete signal $x(n)$ is shifted by m as $x(n-m)$. Obtain the Z-transform $X'(z)$ of $x(n-m)$ and show its derivation.

(3) Now we consider the response of the discrete system whose diagram is given in the figure below. Show the simultaneous difference equations of this system by using an internal state variable $q(n)$.

(4) Obtain the Z-transform of the simultaneous difference equations in Question (3). Assume that the Z-transform of $q(n)$ is $Q(z)$ and the initial value $q(-1) = q_0$.

(5) Using the results of Questions (3) and (4), obtain the zero input response of the system $y(n)$ when $x(n) = 0$.

(6) Suppose that q_0 is zero. Obtain the unit step response of the system $y(n)$ when the unit step signal $u(n)$ shown below is given as the input to the system.

$$u(n) = \begin{cases} 1 & \text{for } n \geq 0, \\ 0 & \text{for } n < 0. \end{cases}$$