information into knowledge, and ultimately knowledge into intelligence. In the GC-MS analysis of dioxins, the data from the instrument are used to determine the identities and amounts of the dioxins present in the sample (information). The information can be used to gain improved knowledge of the operation of the system from which the sample was taken, the relationships between the operating conditions of incinerators, and the amounts of dioxins in their emissions. Finally, this knowledge can be used in the intelligent operation of incinerators to minimize dioxin emissions, possibly using an expert system to monitor and control the incinerator.

PROBLEMS

1. Distinguish between the sensitivity and detection limit.

2. In which of the following measurements has the detection limit been reached? Show calculations to justify your answer.

Measurement	Analyte signal	Blank signal
1	1.52 + 0.05	1.38 + 0.07
2	0.94 + 0.03	0.81 + 0.02

3. What types of noise can be reduced by (a) reducing the bandwidth of measurement frequencies, (b) reducing the temperature of the measurement, and (c) reducing the frequency of the measurement?

4. Calculate the increase in the S/N ratio of a measurement by increasing the integration time from 1.0 sec to 5.0 sec. When is it not advisable to increase integration times as a means to improve the S/N ratio?

5. What types of noise can be reduced by (a) hardware filters, (b) integration of the signal, and (c) modulation/demodulation?

6. What advantages do the following hardware signal enhancement techniques offer over other hardware devices: (a) active filters and (b) boxcar integrators?

7. Explain how the software signal enhancement techniques of boxcar averaging and ensemble averaging complement each other.

8. (a) Calculate the increase in the S/N ratio by ensemble averaging 200 repetitive scans of a spectrum. (b) Discuss the limitations of ensemble averaging in signal enhancement.

9. How are fast Fourier transformations used to reduce noise?

10. Explain the advantages of fast Fourier transformations over ensemble averaging as a signal enhancement technique.

11. What types of experimental error are minimized by hardware and software filtering techniques? Explain.

12. Explain, using an example, how an accurate measurement could contain a large absolute error.

Measurement of Current and Voltage

Obtaining precise measurements of currents and voltages from input transducers is one of the most important functions of op amps. As feedback-stabilized amplifiers, they can increase the magnitude of input signals so that these signals may be more precisely registered by signal modifiers and output transducers.

A combination of the basic op amp summing and scaling circuits is used to measure current (Figure 3.8). An adjustable resistance, *R*, controls the degree of amplification (the sensitivity). Provision is also made for adding a signed current from a controlled source to the input current at summing point *P*. This current, known as either the summing or bucking current, is used to adjust the level of the baseline, such as the dark current correction for photomultiplier output currents.

If the voltage drop across two points in a circuit is to be precisely determined, no current should flow between these points during the measurement. Voltage followers are used to isolate voltage measurement circuits in which no current flow is desirable from signal-modifying circuits where current flow is necessary (Figure 3.9a). These devices transfer voltage signals at the input to the voltage output without causing a current flow in the input circuit. The voltage follower op amp circuit has a gain of unity and provides a noninverted output voltage. The basic op amp properties of high input impedance and low output impedance are responsible

FIGURE **3.8**
Current amplifier.

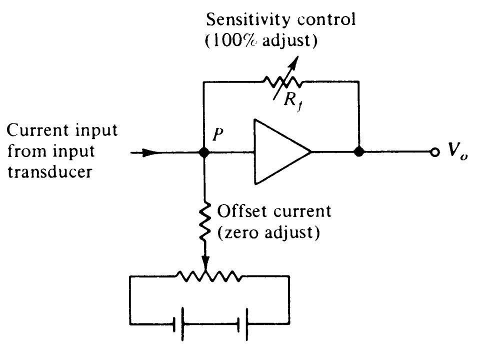
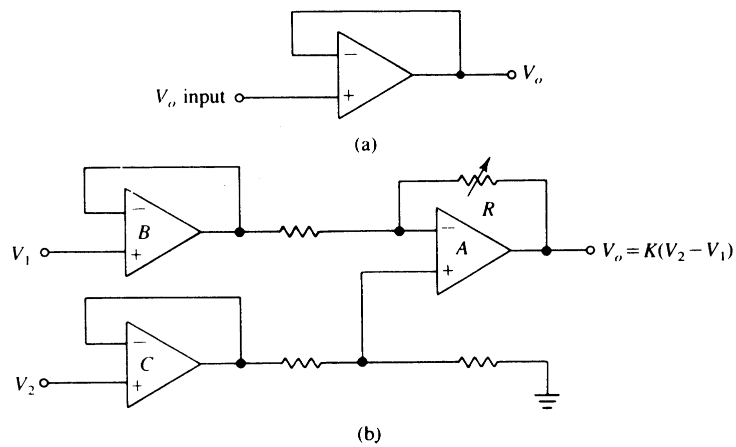


FIGURE **3.9**
Voltage followers: (a) simple voltage follower and (b) instrument amplifier.



This time is the sum of the delay times of the individual flip-flops that make up the counter. Delay times of individual flip-flops—that is, the time between a change in clock input and the resultant change to Q output—are typically 80 nsec per flip-flop. Thus the total propagation delay of a modulo-16 counter containing four flip-flops is 0.32 μsec, which limits the counting rates to 3.0 MHz.

The propagation delay is reduced by the synchronous binary counter, which allows all four flip-flops to change state simultaneously. The input pulse is applied simultaneously to the clock inputs of all the component flip-flops. Logic circuits constructed from flip-flops and auxiliary gates prevent transitions at Q outputs until the appropriate count is reached. The maximum propagation time for the synchronous counter is therefore the delay time of a single flip-flop. Thus the maximum counting rate of a synchronous modulo-16 counter is four times that of the equivalent asynchronous counter.

Binary coded decimal (BCD) counters are used in instruments where the convenience of readout in decimal data is desired. Four interconnected flip-flops form one stage of an asynchronous BCD counter (Figure 3.23). This flip-flop combination represents one digit of a decimal number. Table 3.3 lists the state of each flip-flop Q output as a function of the input count. Each digit requires one stage

FIGURE 3.23

Asynchronous BCD counter.

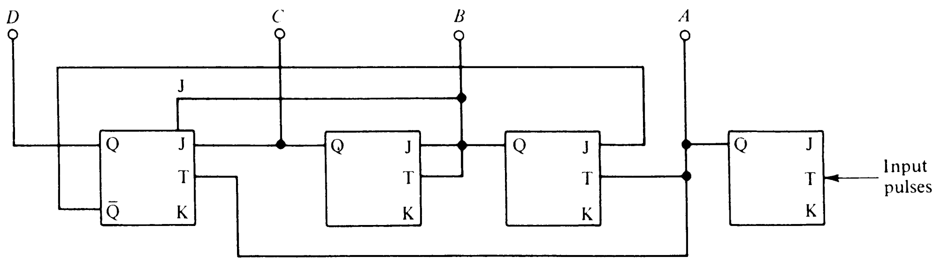


TABLE 3.3

BCD COUNTER OUTPUTS AS A FUNCTION OF COUNT NUMBER

Input count	BCD counter outputs D	C	B	A
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

of binary bits. A bit consists of either a one or a zero. All operations are, therefore, performed using the principles of Boolean algebra. Arithmetic operations include addition and subtraction; logic operations involve "ANDing," ORing," and shifting all the bits of a word to the left or right. Although the number of basic operations performed by any computer is limited, the rapid execution of a series of these instructions, known as an algorithm, can produce many useful functions. Common algorithms include such functions as multiplication, integration, and manipulation of data arrays.

Control Unit

The CU is responsible for coordinating the operation of the entire computer system. Specifically, it generates and manages the control signals necessary to synchronize the flow of data on all buses with the operation of the functional units. The control unit also fetches, decodes, and executes successive instructions (a program) stored in the memory unit.

Central Processing Unit

The control unit is usually physically linked to the arithmetic-logic unit that it manages; the combination of CU and ALU is known as the central processing unit (CPU). Two critical parameters that are needed to evaluate CPU operation are the minimum time required to carry out specific types of instructions and the number of bits in the instructions, memory addresses (program counters), and data processed by the CPU. These parameters determine the rates at which data can be acquired and processed. The first generation of CPU chips, represented by the Motorola 6502, Intel 8080, and the Zilog Z80, processed data and instructions in 8-bit words.

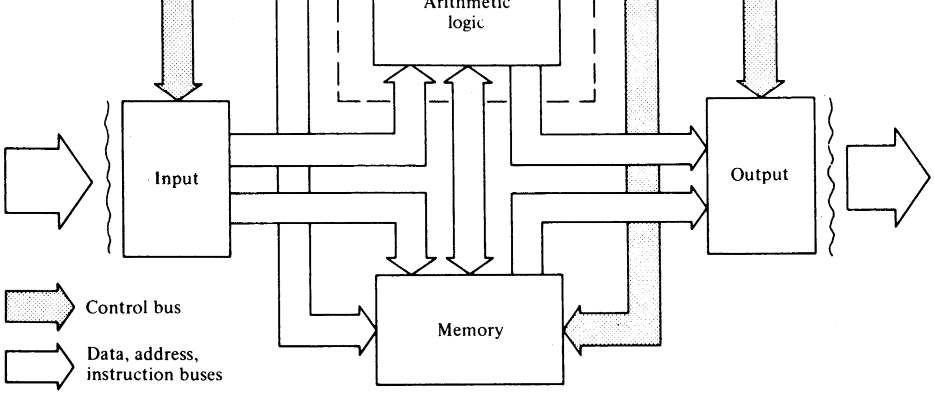


FIGURE 4.5
Basic computer organization.

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