Introduction to Computer Control Systems

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1 Introduction to computer control systems

In the modern cities, many facilities and works are controlled by the automation system and computers, for example, MTR, electricity supply system, traffic light control system, elevators and CNC machines in factories (Fig. 1). There are many advantages of automation system such as the increase in efficiency; reduction of the cost, the number of operators, repetitive and boring work; enhancing the safety of workers; improvement of the working performance and completing the work that cannot be done manually.

Fig. 1 (a) Electricity supply system

(b) CNC machine

(a) The merits of computer control system

Computer is not the only ways to control the automation system, other methods include: mechanical systems, electrical (relay) systems, pneumatic system, electronic system, etc. Yet computer control system has many advantages over the other control systems. For example, it has fast calculation speed, multiple forms of input and output devices, large memory, programmable control, telecommunication possible, small and light, etc.

(i) Fast calculation speed

The central processing unit of modern computers can do a large number of calculations within one second, and it can manage a lot of work and data in a short time. The fast calculation speeds of computer make it possible to control a lot of facilities at the same time under different conditions. For example, the MTR computer system can control trains in different routes to ensure the system runs normally.

Fig. 2 Computer controlled MTR system

(ii) Multiple forms of input and output devices

Computer has many input devices, including keyboard (Fig. 3), mouse, scanner, tape, etc. Moreover, it can also use electronic circuits to transform signals from electronic sensors to digital data and input them to the computer. For example, by using a sensor, the temperature can be transformed into digital data and input in the computer.

Fig 3 Keyboard

After processing the data, the computer can generate output signal. Similarly, computer can use electronic circuits to output digital signals which can then control various output devices, for examples, printer, monitor, relay, motor, electromagnetic detecting valve, etc.

(iii) High capacity of data storage

Computer can use a large number of information storage devices, such as floppy disk, magnetic tape, hard disk, CD-ROM, DVD (Fig. 4), etc. Therefore, computer can use those stored information to perform the controlling work. For example, we can use computer to design complicated shape of workpieces. Then we input the relevant data into the storage device of the CNC machine and let the computer to control the cutting work of the workpieces according to the data.

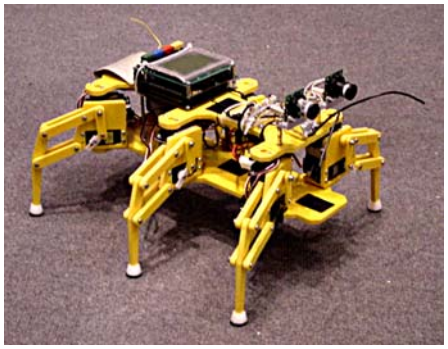


Fig. 4 DVD has high storage capacity Fig. 5 Computer controlled six legs machine

(iv) Programmable control

A program is a set of instructions. Computer can operate according to the program. Therefore, operators can either input new program or modify the existing program to change the working procedures or methods according to the needs. So, computer control system not only can operate those simple task and repetitive work, it can also operate complicated work under different conditions and feedback according to the program. For example, there is a visual system in the computer controlled six legs machine as shown in Fig. 5. The computer of the robot can analyze the image and choose the way without any obstacle.

(v) Telecommunications possible

Computers can be used to input or output digital signals, and using the wires to transmit signals, exchange information and communicate. So, computer information can be transmitted to distant areas by private cables, telephone lines, internet or radio wave. For example, computers can control distant video cameras or machines through the internet; computers can also be used to control spacecrafts in space through the use of radio wave.

Fig. 6 Spacecraft

Fig. 7 Microcomputer controlled car engine

(vi) Small and light

With the advancement of technology, the size and weight of computers have been reduced a lot. The microcomputers developed recently are so sophisticated that it is possible to put the microcomputers into a number of utensils, such as washing machines, refrigerators, air-conditioners, car (Fig. 7), etc. Take the car as an example. For those cars having traditional emulsifier engine, the amount of petrol supply to the engine is controlled by the emulsifier. But nowadays, some of the car has an EFI system that can decide the best amount of petrol supply to the engine according to the amount of air input, air temperature, spinning speed of the engine, coolant's temperature, valves' open width, oxygen concentration in the air vent pipe and other important factors.

(b) The restrictions of computer control system

There are many advantages of the computer control system, but there are some restrictions as well. For example, the cost is high, the maintenance is difficult and the control is complicated. It is difficult to withstand adverse environment and it needs a large amount of accessory devices.

(i) High cost

To design and make a computer control system takes a long period of time. The equipment is expensive and hence at the total cost is high. For example, when a computer is used to control a cutting machine, a suitable set of control program is needed to control the moving path of the tools, moving speed, spinning speed, feeding rate, change of tools, adding of coolants, etc (Fig. 8).

Fig. 8 CNC machine

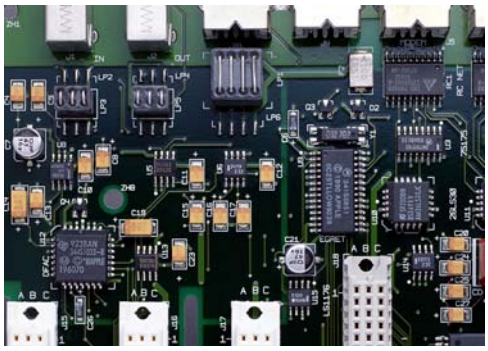


Fig. 9 Electronic circuit board

(ii) Difficulties in maintenance

Nowadays, computers are used in mass production of integrated circuit and electronic circuit board (Fig. 9). They need new parts to replace those damaged. With the rapid development of computer technology, the newly designed parts may not be used in those old-fashioned electronic circuit boards, and so the maintenance will be more difficult. For example, when newly designed random access memory (RAM) is produced, the production of the old designed RAM will cease. After some time, when the old designed RAM is damaged, it cannot be replaced.

(iii) Intolerance under adverse environment

The electronic parts of the computer control system cannot work under bad environment, for example, too hot, too cold, humid, dusty, vigorous vibration (Fig. 10), etc. So, we should avoid using compute control system under these environments. For example, we should avoid using cooling fan to cool down the computer in dusty place.

Fig. 10 Bad working environment

Fig. 11 Cooling fan of a computer

(iv) Requirement of large amount of supporting device

Computers can manage large amount of data in a short time, but it needs some supporting devices to provide information. That is why a computer control system needs many supporting devices. For example, a system is needed to detect the position of the tools and workpieces when a computer is used to control a cutting machine. The system can give feedback to the computer to allow it to control the machine accordingly.

2 Methods of data processing in computer

Computer uses binary numbers 1 and 0 to perform calculations (Fig. 12). A binary digit is known as a bit, while 8 bits can be grouped into a byte. Thus, one or more bytes can be grouped into a word (Fig.13). The central processing unit (CPU) is the main working part of a computer that can process a word, but the length of the word (for example, 16 bits) it can manage depends on the power and design of the computer. A powerful CPU can process a long word faster.

Decimal calculation:

$12_{10}=10+2=1x10^1+2x10^0$

Binary calculation:

$1100_2=1x2^3+1x2^2+0x2^1+0x2^0$

$=8+4$

$=12_{10}$

Fig. 12 Computer using binary system to calculate

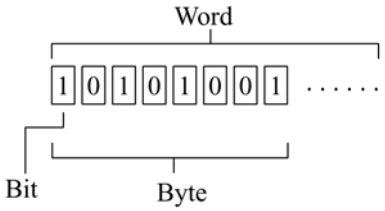


Fig. 13 Bit, byte and word

3 Computer control system

(a) Microprocessor

A microprocessor is a tiny integrated circuit (Fig. 14). It can process large amount of data rapidly. A microprocessor not only can be used as a CPU of a computer, it can also be put into other utensils to broaden its usage. For example, SIM card (Fig. 15), computer sewing machine, computer aided design system, etc. Therefore, its usage is very board.

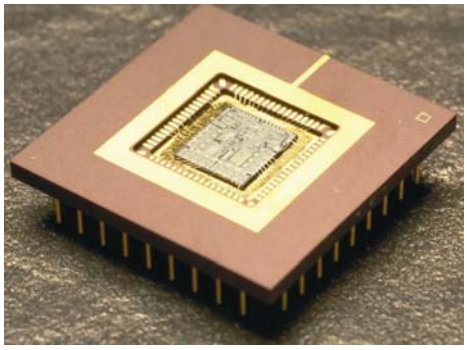


Fig. 14 Microprocessor

Fig. 15 SIM card

(b) The working of the computer control system

In a computer control system, sensors are used to collect data and then input to the computer. There are many kinds of sensors, e.g. thermal sensors, pressure sensors, light sensors, etc. They can produce electrical signals according to external change. For example, light sensitive resistor can be used as a light sensor. It is because its resistance and corresponding current will change with the light intensity of the environment.

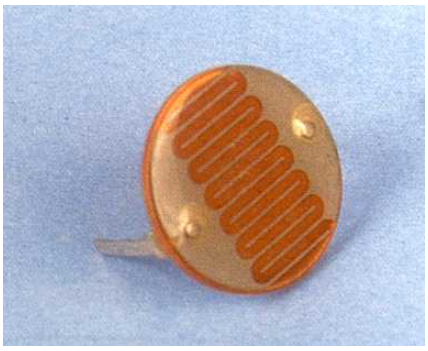


Fig. 16 Light sensitive resistor

Fig. 17 Relay

The computer processes the input signals. It then sends out output signals to the components under its control, e.g. light emitting diode (LED), relay, etc, to respond correspondingly. For example, in an automatic street lighting system, when the computer senses that the light is dim, it will send instructions to the relay. The relay will then turn on the street lamp which uses large current.

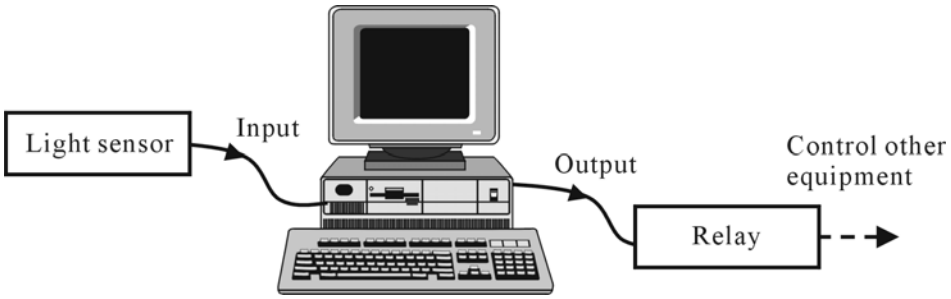


Fig. 18 A computer control system connected to input/output device

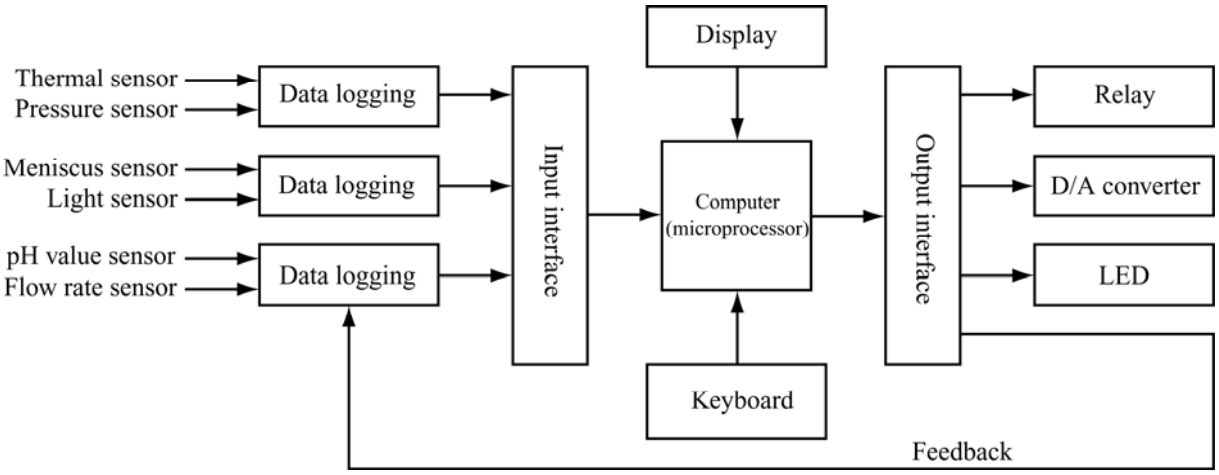


Fig. 19 Block diagram of a common computer control system

However, any input and output signal of the computer needs interface and supplementary equipment. Fig. 19 is the block diagram of a common computer control system. In this system, data collector will firstly collect the data from the sensors, and then changes them into digital signals. Then it will input the data into the computer through the input interface. Keyboard and monitor can be used to input the control value, read the latest processed data and input command, etc. The processed signals will then output to the relay, digital/analogy converter, LED and other execution components through the output interface. The CPU will then command other parts to finish the required work of the program. In the closed loop control system, the output signals will be sent back to the data collector as “feedback”, and the timing machine in the computer will decide the speed of the whole loop.

(c) Interface

Every communication device has an interface, in the form of a hardware or a software. In a computer control system, the interface corresponds to the link between the computer and all other input devices. It can also link the computer to other electronic systems. The input interface (Fig. 20) is responsible for storing and processing the signals from the data collector temporarily. Then it will pass the data to the microprocessor to process and calculate. The output interface is responsible for storing the signals from microprocessor temporarily, and the signals will then be processed to become some controlling commands for other parts.

Fig. 20 The electronic circuit board for output interface (Video card)

To increase the output power, the output signals of computer can be used to drive the electrical, mechanical and pneumatic systems through different output interface. Take pneumatic system as an example. Although some control systems comprised solely pneumatic components, the cost will be higher. And if we use computer to control and install some electro-pneumatic components in the system, the cost will be cheaper. Nowadays, many control valves can work at low voltage.

(d) Example on the application of computer control automation

Fig. 21 shows an electronic notice board. In this example, the computer program will control the LEDs to light at the right time, and arrange them to form different pictures, words or symbols to show the continuously updated information.

Fig. 21 Electronic notice board

4 Flow diagram

In a computer control system, the CPU (e.g. microprocessor) will process data according to the program which is a set of commands. There is a set of rules to follow when writing a program. Therefore, before composing a program, we need to understand the rules of data processing. This can be illustrated using flow diagrams.

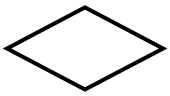
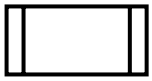
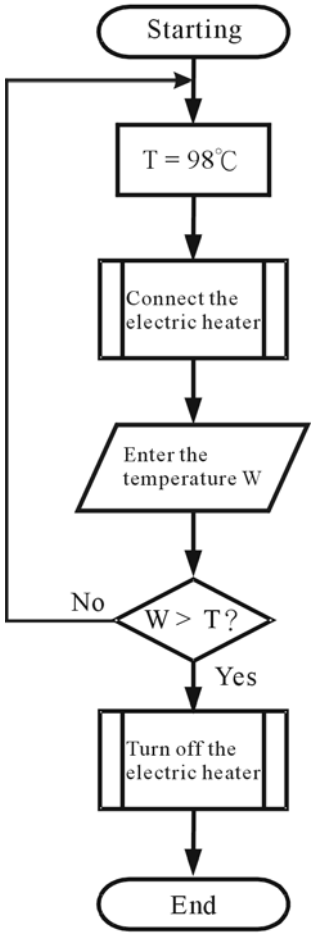
Symbol	Meaning	Explanation
	Starting/End	The starting or end point of the flow diagram.
	Processing	Process a specific work, for example, addition, subtraction, multiplication, division, etc.
	Input/Output	To do an output or input work, for example, inputting some numbers, or inputting some measurements from the temperature sensor.
	Decide	Commonly including a comparative condition. If the condition is met, the work will be done. If the condition is not met, other work will be assigned.
	Sub-program	Sub-program groups a set of work together to form another program. This can be used anywhere in the flow diagram to simplify it.
	Joint	To join two separate flow diagrams (Mark is usually used).
	Joint to other page	To join two flow diagrams on different pages (Mark is usually used).

Table 1 Some common symbols of flow diagram

A flow diagram uses different symbols to represent different jobs. Table 1 shows some of the commonly used symbols and their meanings. Fig. 22 is an example of a flow diagram that describes how to control an electric heater to heat up the water to the required temperature. This flow diagram can assist in composing a program.



Set the required temperature of 98'C into the variable T.

Switch on the electric heater to heat up water. Use sub-program to control the procedures of the switching on the electric heater.

The temperature measured by the temperature sensor is entered into the variable W.

Compare the values entered into the variable W and T to make decision.

If the value of variable W is larger than the value of variable T, then turn off the electric heater. Use sub-program to control the turn off procedure of the electric heater.

Fig. 22 An example of flow diagram

5 The concept of composing control program

A computer program is a set of instructions. These instructions control the computer to process the data input. The following figure shows an example of a computer program. In the program, the lines of instructions follow in order, and the computer will process the input data according to their order. Data and commands can be numbers, alphabets, punctuation or symbols, collectively called the characters.

```
10 INPUT X          (input  a number and then put it into X)
20 X = X + 1        (add one to the number in X and then put it into X)
30 PRINT X          (print out the number in X)
40 END              (End of program)
```

Fig. 23 An example of a computer program (BASIC)

The language used in composing a computer program must be understood. So the program has to be translated into binary numbers which computer can process. The language used in composing a computer program can be merely classified into high level languages and low level languages.

(a) High level languages and low level languages

The computer programs that are relatively similar to human language are called high level languages. Every command will instruct the computer to do certain job. High level languages includes: BASIC, PASCAL, C, etc. High level languages are easier to use and understand, but it requires a relatively long time to translate into binary numbers which the computer can process. The operating speed is usually slower. If higher speed is required, we can use some compilers to translate the program beforehand. The languages that are closer to the computer program language are called low level languages, while their operation speed are relatively higher. Low level languages includes: machine code, assembly language, etc. Low level languages are used more commonly in a computer control system to increase the operating speed of the system.

Fig. 24 is a program composed by using BASIC. It controls the electric heater based on the procedures of the flow diagram in Fig. 22.

BASIC program	Explanation
100 T=98	Set the required temperature of 98^{o}C into the variable T.
110 GOSUB HEATER _ON	Switch on the electric heater to heat up water. Use sub-program to control the procedures of switching on the electric heater.
120 W = SENSOR	The temperature value measured by the temperature sensor is entered into the variable W.
130 IF W>T THEN 120 ELSE 140	Compare the values entered into the variable W and T to make the decision.
140 GOSUB HEATER_OFF	If the value of variable W is larger than the value of variable T, then turn off the electric heater. Use sub-program to control the turn off procedure of the electric heater.

Fig. 24 Control program composed by using BASIC

(b) Machine code

Binary number is used in the processor of computer. Different arrangement of numbers represents different simple command, and they are collectively called machine code. Binary numbers are composed of 1 and 0, which each of them called a bit. As a processor can process a command that is composed by 8 bits at one time, then the command may be arranged as follows: 1011 0111, 10001101, 0111 0010, etc.

Hexadecimal numbers is another simple method that can be used to represent machine code. Table 2 shows their symbols. Hexadecimal numbers can be converted into binary numbers:

$$B_{16} = 11_{10} = 8 + 0 + 2 + 1 = 1\times2^3 + 0\times2^2 + 1\times2^1 + 1\times2^0 = 1011_2$$

$$B3_{16} = 11x16^1 + 3x2^0 = 176 + 3 = 179_{10} \qquad = 1011\ 0011_2$$

$$FF_{16} = 15x16^1 + 15x2^0 = 240 + 15 = 255_{10} = 1111\ 1111_2$$

Fig. 25

Fig. 25 also shows that each hexadecimal number can be represented by a combination of 4 binary digits. Therefore, an 8-bits command can be simplified into 2 hexadecimal numbers command. For example: 1011 0011 can be represented by B3, 1111 1111 can be represented by FF.

Decimal number	Binary number	Hexadecimal number
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Table 2 An exchange table of hexadecimal number

Obviously, it is much easier to use hexadecimal numbers as machine codes when composing a program, but it is necessary to remember the representation of every code. More than that, every microprocessor has its own specific machine code. It is necessary for us to refer to that specific machine code table when composing machine code program.

(c) Assembly language

Another programming language that is similar to human language is the assembly language. Different types of microprocessor may have its own assembly language. The commands of the assembly language are simple English. For example: LDA represents the taking out of data from the accumulator of a computer, JSR represents the jumping to the sub-program etc. Every command is usually composed by two parts, the first part corresponding to the processing work, called operation code. It instructs the operation of computer. The following part is the data required by the operation, called operand or arithmetic element.

After composing the program using instruction sentences, we have to assemblage the whole program into the corresponding binary number machine code for the computer to run. This assemblage work can be done manually or by some special software called assembler.

6 The basic theory of programming

There are some basic theories we have to pay attention to when composing a program. This will save time on designing, composing and debugging.

(a) The use of systematic method

A good programmer can compose a program independently. But when the program becomes much larger and complicated, a group of programmers will need to cooperate with each other. So a systematic method and some standardized tools will be needed to help the collaboration.

A common systematic method is a design from the top to the bottom. Firstly, divide the whole program into a number of main sections, called main module. Then use some simple block diagram to show the relations between each modules (Fig. 26a). Every main module can then be divided into some smaller modules, and some simple block diagrams can be drawn again to represent the relations between these smaller modules (Fig. 26b). And this kind of breaking-up process can continue until we reach the simplest modules.

Therefore, every programmer can be assigned some modules of the program.

The advantage of this method is that a blue print can be used to show the whole system, and some smaller details can be found according to the needs. Beside this, because the relation between each section is clear, it is easier for the bug detection and modification process of the program.

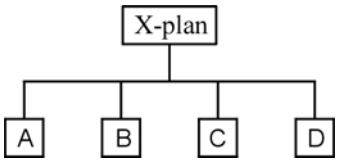
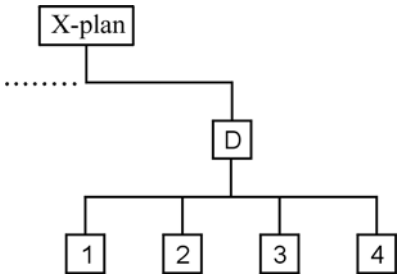


Fig. 26 (a) The whole system is divided into few main modules



(b) The main modules are then divided into some smaller modules.

(b) A meaningful name is preferable

When composing a program, we should not choose some meaningless words or some simple alphabets as the name of the modules or variables. This will make the program relatively hard to understand, and also it would be difficult for later modifications of the program. So, a meaningful name that links to the related function is preferable. For example, if we use a computer program to control the furnace temperature, we may use FURNACE_TEMP to represent it. Hence, we can understand the program more easily.

However, some programs may not allow logical names, for example, assembly language. But it is possible to add some sentences in the program to explain the meaning of the codes. Although this will decrease the speed of coding, it will delay the speed of debugging.

(c) Composing the initializing module

A program can include different modules (for example, sub-program), and the one that should be composed firstly is the initializing module. The functions of initializing module are to clear all the original programmes in the computer memory, and to restore and re-assign the cables for input and output. The initializing module should be saved after composing, so that it can be used again later.

(d) Deciding the input-output and processing modules

A program usually consists of different input, output and processing modules. Output modules correspond to the transfer of signals to the electronic circuits that are out of the system, and there is no feedback available. The program will keep running after these modules are processed.

Processing modules require the input of at least one signal, and it will give out a signal as feedback. For example, in a binary number system to decimal number system converting module, the input binary number will be processed and converted into decimal number, and the resulting decimal number will be fed back to the program.

Input modules correspond to collecting information from the electronic circuits that are out of the system, and they also correspond to the transfer of that information into the program. For example, the module corresponds to the reading of signals or checking of a specific word's condition at the interface port.

(e) Adding the debugging decide

There are always some mistakes when composing a complicated program. It is better to add some debugging design in different parts to avoid wrong interruption of the program. For example, when the pressing of "Y" or "N" button on the keyboard is assigned for the next step of the program, we should make sure that there will be no response when any other button is pressed. This design can make the program more user-friendly.

(f) Beware of execution mode

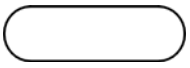
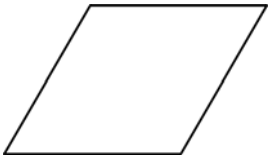
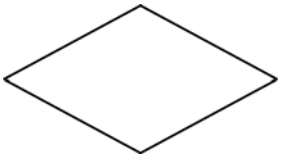
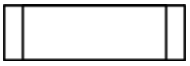
The output value should not impose any bad influence wherever the program executes. If not, the influenced equipment will stay and keep running at the last mode. For example, the washing machine should stop running whenever the control program is executed, if not, the washing machine will keep running continuously.

Interactive information

	Address	Brief contents	Language
1	http://www.wes-tech.com/	A website that introduces automated production machines.	English

Exercise

1. What are the advantages of using computer control system?
2. What are the functions of the analogue converter in the computer control system?
3. How to classify computers according to their sizes and abilities?
4. What are the characters in a program?
5. List those languages used in composing computer programmes.
6. Although there are merits of a computer control system, limitations do exist. Write the limitations in using a computer control system.
7. What are the basic principles to be followed in composing a computer control program?
8. Fill in the following table for the meaning of the corresponding symbol of the flow diagram.

Symbol	Meaning
	
	
	
	

9. For safety reason, a burglar alarm system has to be installed in the computer room of the school. This alarm system should include a magnetic sensor at front door (1), magnetic sensor at the window (2) and a infra red sensor (3). When any one of them operates, the alarm system sends out a siren. The system should be equipped with a switch and repetitive device.

   For the above requirements, design a flow diagram of the control program for the burglar alarm system in the computer room.