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공압회로 설계를 위한 소프트웨어의 개발

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Design of A Computer Software for Pneumatic Circuits

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ABSTRACT

A computer software which can draw and analyze pneumatic circuits was developed for the purpose of introducing and educating pneumatic circuits to beginners in this field. The program was developed using Turbo Pascal and Turbo Pascal Graphix Toolbox and could be run on IBM PC, XT, AT and other IBM compatible computers with a Hercules Graphics Board.

The program was developed to show sequential control characteristics and to show two stages (on and off) of the pneumatic actuators. Users may save much time in drawing complex pneumatic circuits and can also use this software to check whether circuits are property designed before constructing real pneumatic circuits.

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1. INTRODUCTION

There are a number of economic and social factors which provide the motivation for automation in manufacturing[1]. The automated production systems can be classified into two basic types, such as flexible automation and fixed automation. In flexible automation, the production equipment is designed to be flexible with programmable machine tools such as CNC machining centers and robots. In fixed automation, the sequence of processing operations in the system is fixed by the equipment configuration. The typical fixed automation examples are the transfer lines of car manufacturing lines and other mass production system. The usual means for material transfer in transfer line systems are hydraulic and pneumatic systems.

Pneumatic systems are usually used in the sequential control of equipment because of the compressibility of air, though there has been a report of development of pneumatic servo systems from West Germany. In spite of this limitation, pneumatic systems are increasingly used in many transfer lines, assembly operations, and low cost automation for medium and small companies because the air is clean, non-toxic and cheap.

There has been much demand to simulate the operation sequence of pneumatic systems before constructing real pneumatic circuit systems. Without pneumatic equipments, we might simulate the pneumatic circuit system by drawing on the paper if the circuit system is very simple. This method is not feasible if the number of pneumatic elements of the circuit are more than 20 because it is very difficult to follow the process of the pneumatic circuit and time consuming to write down the circuits in the paper.

In order to solve these problems a computer software is sought, which can draw and analyze pneumatic circuits. For the computer-aided design and analysis software, there have been some reports in hydraulic systems. Don Riley[2] made a software which can design and simulate hydraulic circuits. He used several commercial computer aided design and drafting softwares and a CD/2000 computer system. In pneumatic systems, it is not easy to find a software which can design and simulate pneumatic circuits using personal computers.

Therefore, we attempted to develop a software which can be run on IBM PC, XT, AT, and other IBM compatible computers. For the first attempt, we have developed a software which can be run only on the Hercules Graphics card. For the graphics software, Turbo Graphix Toolbox has been chosen rather than special graphics software such as Auto CAD, because Turbo Graphix Toolbox is easily accessible and manageable in terms of data. The version 3.0 of Turbo Pascal software was used even though we can obtain more updated version, because version 3.0 was popular when the software was developed. Accordingly, the program has limitations on the number of the pneumatic equipment and the resolutions that can be used, since the version 3.0 has 64k byte memory limitation[3] and Hercules board has 720 by 350 pixels[4]. Since programs developed with 3.0 version of Turbo Pascal can by easily converted to updated version, this does not present a big obstacle. Users who want to accommodate more than 50 pneumatic elements may use updated version of Turbo Pascal and convert the developed software from version 3.0 to updated version.

The program was developed to show only sequential control characteristics and to show two stages(on and off) of pneumatic actuators which have feedback elements. We did not attempt to solve the quantitative nature inside the circuit such as pressure drop since the air flow phenomena inside the pneumatic circuit is not easy to analyze because of the compressibility of the air.

After applying this software to several pneumatic circuit systems, we found that the software could be used in the design and analysis of real industrial pneumatic circuit systems.

2. OVERVIEW OF THE PROGRAM

The program PSD(Pneumatic System Designer) developed in this work consists of two parts, i. e., the pneumatic circuit drawing part and the circuit analyzing part. In the circuit drawing part, a pneumatic circuit can be designed graphically on the CRT of the computer by selecting the pneumatic devices from the menus(Fig. 1), moving them into appropriate positions of the screen and connecting them with lines. It serves as a kind of the CAD(Computer Aided Drawing) systems for pneumatic circuit systems and gives convenience in drawing a pneumatic circuit.

In order for PSD to be used in the educational and practical design purposes, most of the pneumatic devices frequently used in constructing pneumatic circuits were stored in the database and they are shown in Fig. 2.

In the circuit analyzing part, the program was developed to show the simulation process graphically on the CRT. The operational informations of the pneumatic devices, such as element type, required switching pressure, actuating speed and operating methods(spring return, push button and etc.) were already given

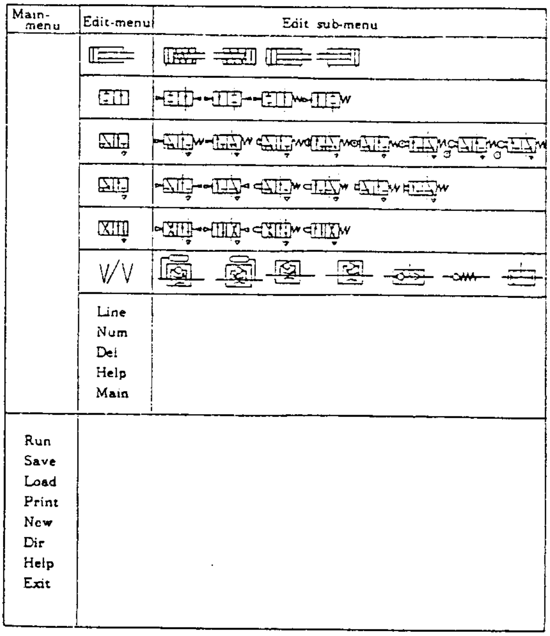


Fig. 1 All usable menus of Pneumatic System Designer

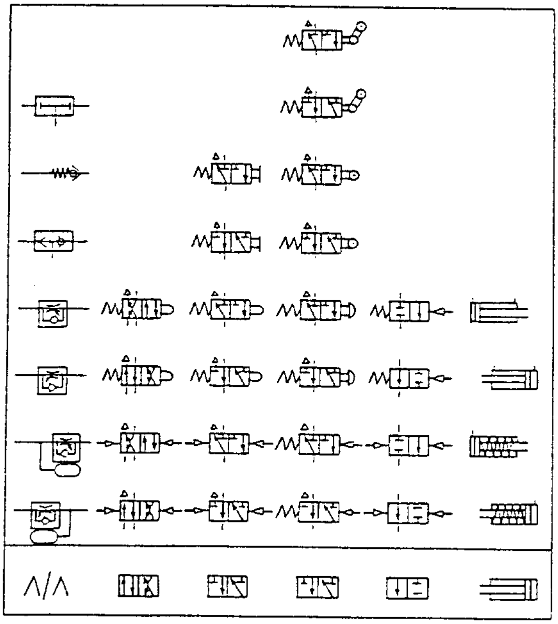
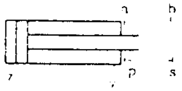
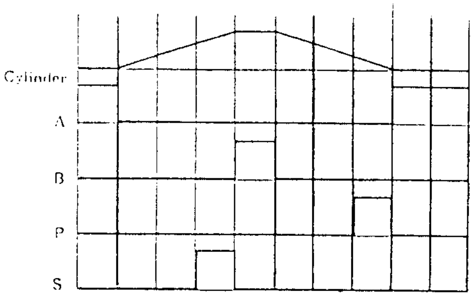


Fig. 2 Usable pneumatic devices of Pneumatic System Designer



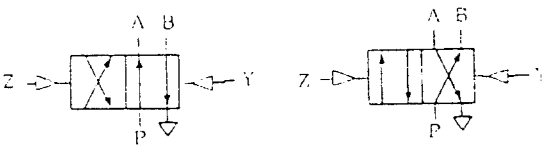
a, b : roller switch
p, s : idle return switch



displacement - time diagram of the cylinder

Z, Y	rate (1)	operation	ss (2)
Z > Y	rate = 0	* (4)	0
	rate > 0	rate=rate-1	. 0
Z < Y	rate = S(3)	*	1
	rate < S	rate=rate+1	1
else	+(5)	*	*

Operation table of the cylinder



type 1 type 2

Z, Y	rate	Operation
Z > Y	rate = 0	P→A, O→B
	rate > 0	rate = rate − 1
Z < Y	rate = S	P→B, O→A
	rate < S	·rate = rate + 1
else	+	*

Operation table of the 4/2 way valve of type 1

Y > Z P ← A : type 1
Y < Z P ← A : type 2

(1) rate is the state of an element.

(2) ss is the moving direction of a cylinder (forward or backward).

(3) s is the delay rate of an element.

(4) +: don't care

(5) *: no operation

Fig. 3 Operational algorithm of the typical pneumatic devices.

as a table format in the PSD(Fig. 3). Other data for analysis are internally generated and managed when the circuit is drawn at the circuit drawing stage and no extra input data are required. When the pneumatic circuits are simulated, the states of the pneumatic devices are determined using these data.

The characteristics of the sequence control systems is that they progress step by step according to the previously given sequence or judgement. Since pneumatic systems are generally applied to the sequence control except they are used as simple actuators, PSD has been programmed on the premise that they are used as the sequence control circuits with feed back elements.

For the purpose of effective management of the control signal, pneumatic pressure was divided into discrete steps. It was divided into ten steps from minimum pressure 1 to the maximum pressure 10 and thd state of the open air was set to 0.

Although system pressure changes continuously, logic devices such as valves are activated by two signals(Higher/Lower than the required switching pressure) and these two signals are called On/Off states. Therefore, it was assumed that the logic devices have On/Off states and other devices such as actuators and relief valves have several states which were set at the data generation time to give the appropriate operational speed to the pneumatic devices.

The program PSD has been developed with PASCAL language and programmed to be run on an IBM PC, XT, AT or their compatibles with a Hercules Graphics card. PSD can simulate pneumatic circuits with no more than 50 devices owing to the limitations of the computer memory and the CRT resolution. The block diagram of the program is shown in Fig. 4.

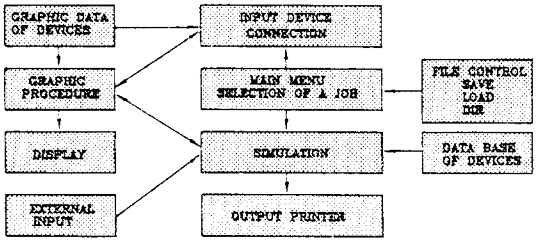


Fig. 4 Block diagram of Pneumatic System Designer

3. DATA STRUCTURE OF THE PNEUMATIC CIRCUIT SYSTEMS

For the simulation of the pneumatic circuit system, it is required to define the relationships between the pneumatic devices. While the date representation of the individual pneumatic devices can be simply realized by the operation principles as in Fig. 3, it is not easy to determine where and how to locate the information about the relationships between pneumatic devices.

The pneumatic devices and the circuit lines are represented by several points which we call nodes. The nodes are grouped into element nodes and branch nodes. The pneumatic devices are represented by the element nodes and the circuit lines which connect the pneumatic devices are represented by the branch nodes.

PSD has been programmed to assign the pneumatic devices to the corresponding element nodes in the data structure when the pneumatic devices were selected from the element menus(Fig. 1). Also, the connection of the pneumatic devices with lines produces the corresponding branch nodes and links them to the element nodes. These two type nodes construct the data structure of the pneumatic circuit system in PSD.

The element nodes also have the individual data such as the operational characteristics and actuating speed of the device, and also has the related data such as the present state, the last state, the identity numbers of the linked branches and the data for graphic handling. These individual data already have been determined when the devices were drawn from the menus.

There are three types in the branch nodes : general, spring and switch branch nodes. The general branch node represents the pneumatic line and just transmits the information into other branches. The spring branch node plays a role of the return spring. When the control pressure disappeared, it returns back the pneumatic device. The switch branch node serves as a lever, a slide or a push button switch. It has two main roles. First, it receives the start and stop signals from the outside of the program and transmits them into the linked branches.

Second, it works as a limit switch of the actuator. The branch node also has its state information, the data of the other linked branches and the data for graphic handling.

There are some other special nodes for power sources and external inputs besides the branch and the element nodes. The connection of these nodes are depicted in Fig. 5 as a block diagram.

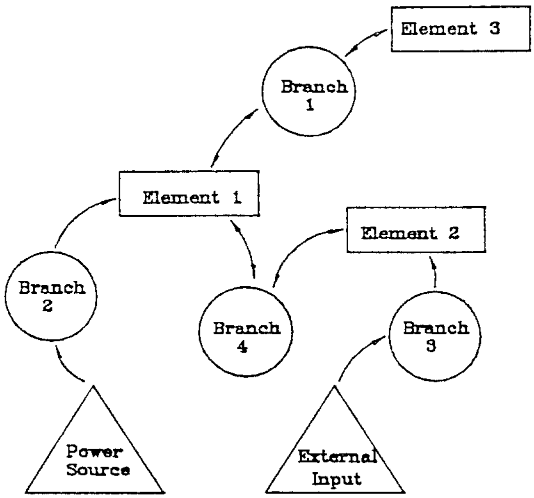


Fig. 5 Block diagram of the node linkage

4. ALGORITHMS

The data structure of the program which consists of the element nodes and the branch nodes is constructed and linked when the pneumatic circuit is designed by the menu driven method in the circuit drawing part. To analyze and simulate the designed pneumatic circuit, the program preprocesses several steps. First, it initializes the whole data and groups them (grouping). Since the branch nodes which are linked with the same line have the same pressure, grouping classifies them into the same group. The branch nodes in the same group have the same state, therefore, one operation on the group determines the states of all the branch nodes in it. This decreases much the processing time of the computer. The grouping is started from any one branch node and traced recursively to other branch nodes which are linked with the same line.

The linked branch nodes are constructed with "doubly linked list" which has the informations about each other[5]. Starting from any one untagged branch node, all the branch nodes which belong to the same group are tagged. If there are branch nodes which are not tagged, the PSD repeats the previous process until there is no untagged branch node. This finishes the grouping.

After the preprocess, the program starts the simulation of the pneumatic circuit. To analyze the states of the pneumatic devices and the lines, the standard time of the operation is required. The speed of the pneumatic signal which flows through the pneumatic lines in 40~70m/sec in normal pressure pneumatic sysyems, and the switching time of the pneumatic devices is more than 10 msec[6]. If the length of the line is long, wrong or unnecessary operational result would come out because the signal transmission time through the line is too long compared with the switching time of the devices. Sometimes, in the sequence control pneumatic circuits, the line length is a few meters which requires more than 20msec for signal transmission but the other pneumatic devices operate only after the required signal arrives. Therefore, the signal propagation time does not make any problem in the sequence control of the pneumatic systems. So, the standard time of the pneumatic circuit operation was chosen on the basis of the state change of the pneumatic device.

The first step of the simulation is to check the existence of an external input. If there is an external input, the program detemines which device the input goes into and stores the data into the buffer memory of the corresponding node.

The second step is to determine the states of the branch nodes from the previous data. The states of the grouped branch nodes are determined by giving priorities to the pressure. The highest priority was given to the open state, i.e., pressure 0, and the next priorities were given from the maximum pressure 10 to the minimum pressure 1 in order. To decide the pressure of the group, the program compares the priorities of the states of the whole branch nodes of the group and the pressure which has the highest priority is determined as the pressure of the group.

In the third step, one operation of the pneumatic devices is performed. The states of the pneumatic devices are decided according to the operation table already shown in Fig. 3.

In the fourth step, the states of the branch nodes are again determined from the changed conditions because the standard time of the operation of the pneumatic circuit is based on the pneumatic devices. In this step, an equivalent operation to the second step without the external input requirement is performed. Finally, the graphics of the changed states of the pneumatic circuits are arranged for the CRT display of the simulation. Fig. 6 shows the flow chart of the simulation.

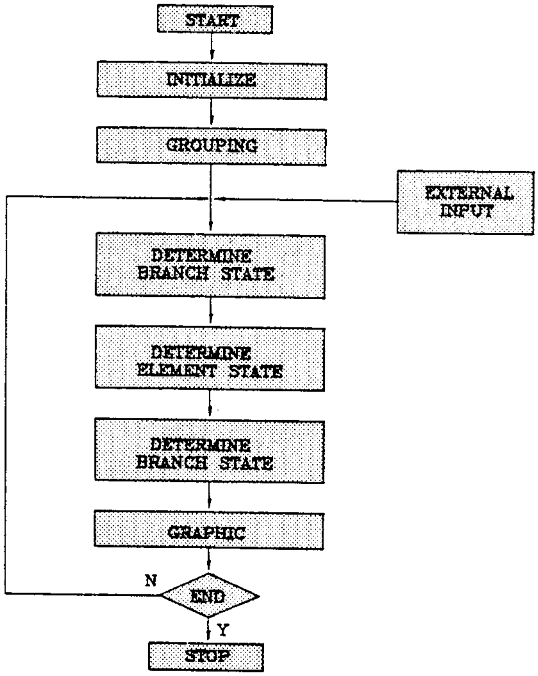


Fig. 6 Flow chart of the pneumatic circuit simulation

5. GRAPHIC PROCEDURE

In the process of the simulation of the pneumatic circuits, the motion of the actuators (cylinders) and valves must be shown on the CRT. Therefore, the graphic procedure for the pneumatic circuits should be developed.

The processing time would be too long if the continuous changing pressures and the pneumatic device actions are shown with smooth changing graphics. However, since the On/Off states are important in the pneumatic sequence control circuit, the complex graphic procedure is not necessary. Therefore, in this study, On/Off states of the pneumatic devices are expressed graphically and the line is expressed with only High/Low pressures. The On/Off symbols of the state of the pneumatic devices are stored in the computer memory for the CRT display. The high pressure line is drawn with the thick line and the low pressure is drawn with the thin line.

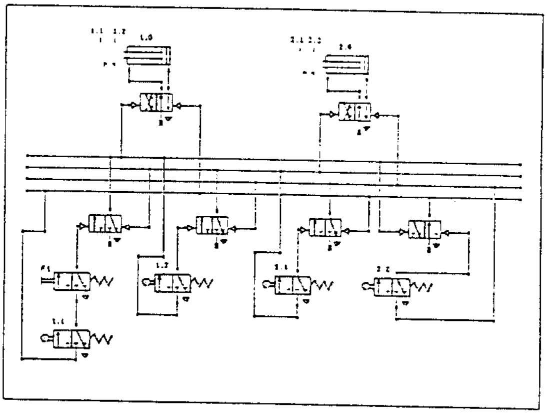


Fig. 7 An example circuit designed by shift register method

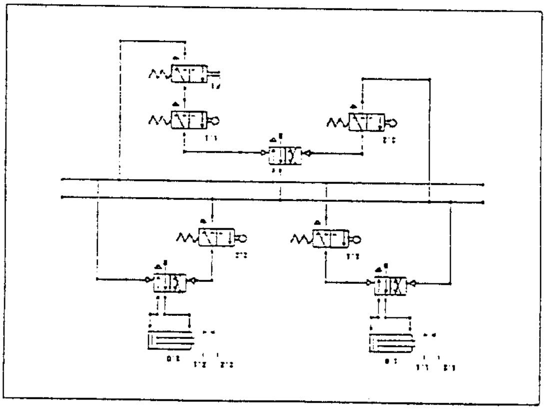


Fig. 8 An example circuit designed by block method

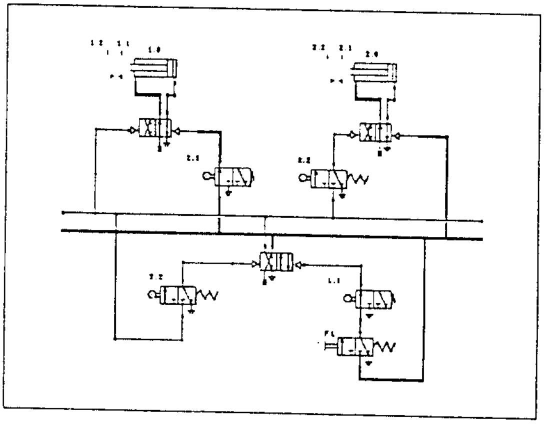


Fig. 9 Simulation process of Fig. 8 (1st step)

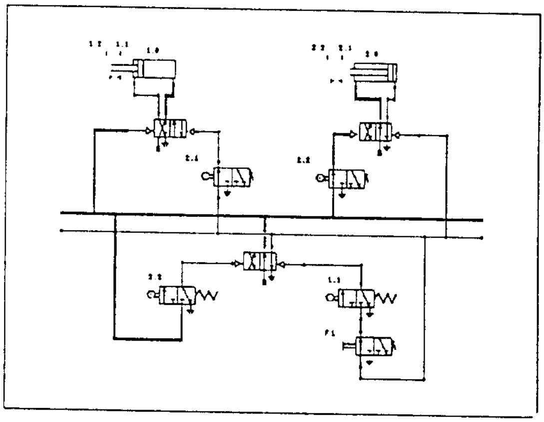


Fig. 10 Simulation process of Fig. 8 (8th step)

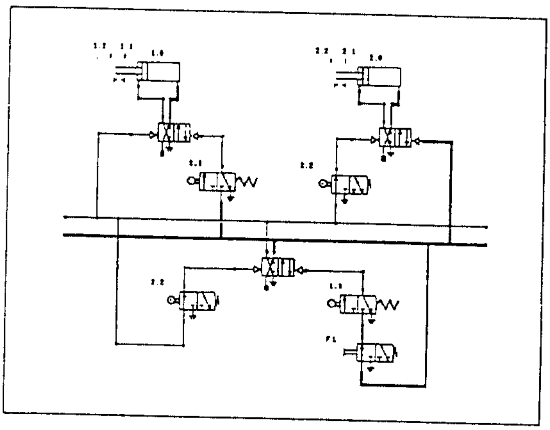


Fig. 11 Simulation process of Fig. 8 (14th step)

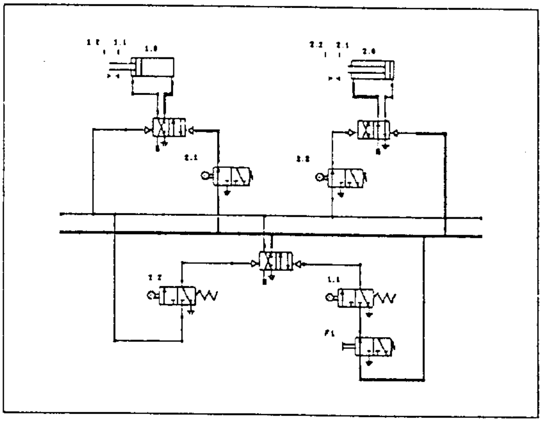


Fig. 12 Simulation process of Fig. 8 (18th step)

6. EXAMPLES

Fig. 7 shows the circuit for a reveter through shift method〔6〕. The working cycle of the reveter consists of the clamping component(cylinder 1.0) and the revetting component(cylinder2.0).Fig. 8 shows the same circuit as Fig. 7 through Block method〔6〕.

Fig. 9 to Fig. 12 show some steps of 22 simulation stages of the circuit of Fig. 8. Fig. 9 is the last stage of the previous motion. Fig. 10 shows the clamping cycle(cylinder 1.0 moves forward). Fig. 11 shows the revetting operation in which cylinder 2.0 moves forward. Fig. 12 shows the retreating operation of the revet-er(cylinder2.0moves backward). After the stage of Fig. 12, the circuit restores to the original stage(Fig. 9).

7. CONCLUSIONS

A pneumatic system designer(PSD) can draw a pneumatic circuit on the CRT of the computer with a menu driven method and simulate the designed circuit graphically. The PSD makes it easy to draw a pneumatic circuit and detect the errors of the circuit before they are implemented. Although this program has some limitations because it is programmed in personal computer, it can be extended easily by changing environments(computer and program language). This gives a probability of the progressive pneumatic CAD(Computer Aided Design) system which approaches the expert system.

PSD may be useful in simple industrial pneumatic design and helps those who are interested in the pneumatic automation.

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