Chapter 4

Basics pneumatics circuits

PREPARED BY U TINT ZAW

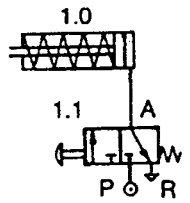
Basic Circuits

Control of a Single-Acting Cylinder

Problem:

The piston of a single-acting cylinder is to move out when a pushbutton is operated; on releasing the pushbutton, the cylinder is to travel back to the end position.

Solution:



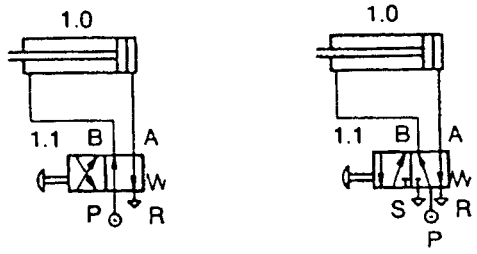
When the 3/2-way valve is operated, air flows from P to A and exhaust port R is blocked. When the pushbutton is released, the valve is reset by the spring. The cylinder chamber and the compressed air line exhaust from A to R, and the compressed air port P is closed.

Control of a Double-Acting Cylinder

Problem:

The piston of a double-acting cylinder is to move out when a pushbutton is operated; when the pushbutton is released, the cylinder is to travel back into the end position.

Solution:



The double-acting cylinder can be reversed either by a 4/2-way or a 5/2-way valve.

In the normal position of the 4/2-way valve, P is connected with B and A is connected with R. By operating the pushbutton, the valve reverses. P is connected with A and B with R. The cylinder piston travels from the rear to the front end position.

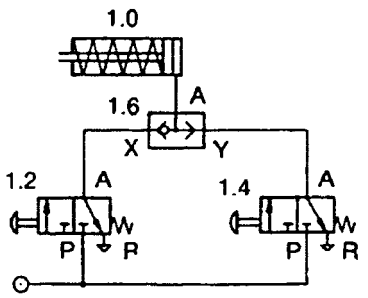
In the normal position of the 5/2-way valve, P is connected with B and A with R. By operating the pushbutton, the valve reverses. P is connected with A and B with S. The piston of the cylinder travels from the rear to the front end position.

Control with Shuttle Valve

Problem:

The advance movement of a single-acting cylinder is to be effected from two different points.

Solution:



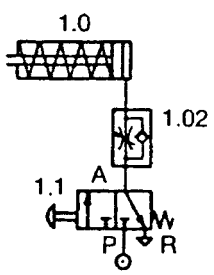
When valve 1.2 is operated, the compressed air flows from P to A, and with valve 1.6 from X to A, to the cylinder. The same occurs when valve 1.4 is operated. The compressed air flows from P to A, on valve 1.6 from Y to A, to the cylinder. If shuttle valve 1.6 were not there, the air would escape through the exhaust of the other non-operated valve on operation of 1.2 or 1.4.

Speed Regulation on Single-Acting Cylinders (One-way Flow Control Valve)

Problem:

The piston speed of a single-acting cylinder is to be adjustable for the advance movement.

Solution:

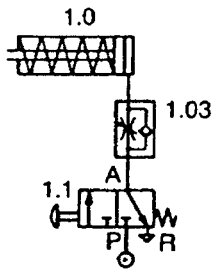


With a single-acting cylinder, the advance movement can be throttled only by throttling the supply air.

Problem:

The piston speed is to be adjustable for the return movement.

Solution:

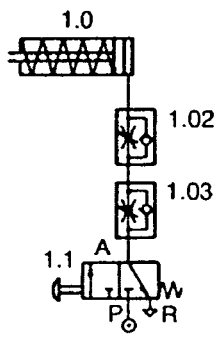


There is no option here but to use exhaust air throttling.

Problem:

The piston speed of a single-acting cylinder is to be adjustable for the advance and return movement and separately throttled.

Solution:



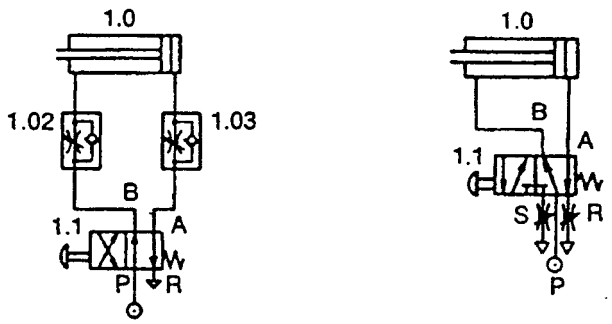
In this case, two one-way flow control valves should be used to provide accurate and separate adjustment.

Speed Regulation on Double-Acting Cylinders

Problem:

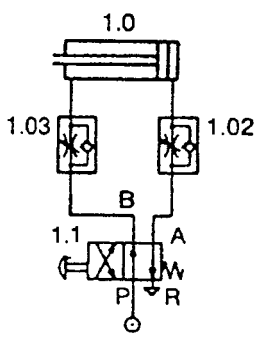
The advance and return movement speeds of a double-acting cylinder are to be regulated.

Solution: a)



a) Separately adjustable exhaust throttling for advance and return movement. Initial jolt until forces are equalised, but then better possibility for regulating (independent of load). With 4/2-way valves, one-way flow control valves must be used. With 5/2-way valves, two flow control valves are adequate.

Solution: b)



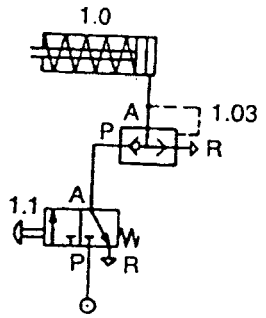
b) Separately adjustable supply air throttling for advance and return movement. Steady initial motion, but poor possibility of regulation. Cannot be applied for pulling loads.

Raising the Speed of Single-Acting and Double-Acting Cylinders (Quick Exhaust Valve)

Problem:

The return speed of a single-acting cylinder is to be increased.

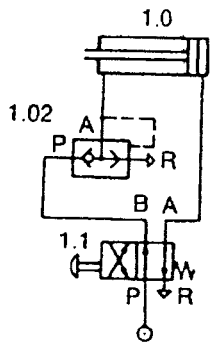
Solution:



Problem:

The speed of the advance movement of a double-acting cylinder should be increased.

Solution:



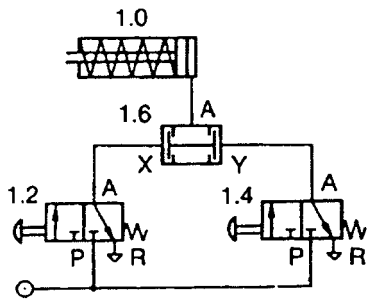
A quick exhaust valve provides for quick exhaust of the cylinder chamber and of the connecting line.

Control with Two-Pressure Valve and Series Connection

Problem:

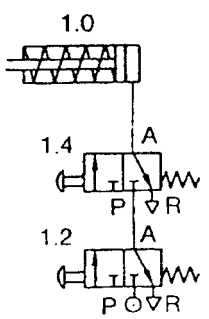
The piston rod of a single-acting cylinder may move out only if two 3/2-way valves are operated.

Solution: a) Two-pressure valve

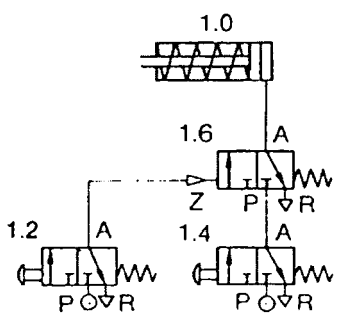


a) Operation of valves 1.2 and 1.4 produces a signal X and Y on the two-pressure valve (1.6), and thus the compressed air is applied to the cylinder.

Solution: b) Series connection



Solution: c)



b) Valves 1.2 and 1.4 must be operated before the single-acting cylinder can move out. (Series connection)

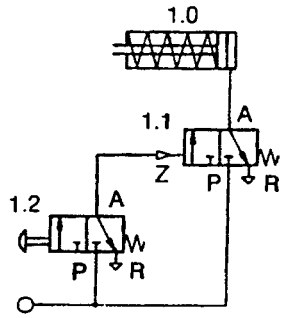
c) Valves 1.2 and 1.4 must be operated. Valve 1.6 assumes the AND function. Valve 1.6 is switched over by valve 1.2 at control port Z, compressed air from valve 1.4 flows through the port P.

Indirect Control of a Single-Acting Cylinder

Problem:

The piston of a large-volume single-acting cylinder (large diameter, large stroke length, large distance from valve to cylinder) is to move out after operating a valve and return to its end position after this valve has been released.

Solution:



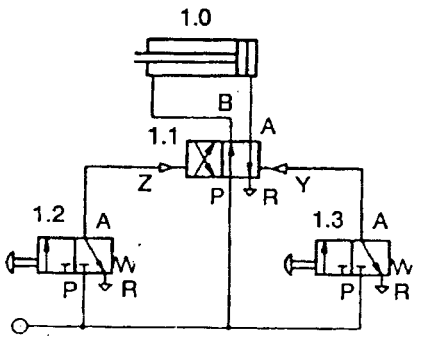
Operation of valve 1.2 opens the passage for the compressed air from P to A, and hence signal at Z on valve 1.1. Owing to switchover of valve 1.1, air flows from P to A and thus the forward stroke is effected on the single-acting cylinder.

Indirect Control of a Double-Acting Cylinder

Problem:

A double-acting cylinder is to be controlled by two valves (1.2 and 1.3) such that the piston travels out when valve 1.2 is operated, and also remain stationary in the forward end position when valve 1.2 is released until the reverse signal is input through valve 1.3 for the return movement.

Solution:



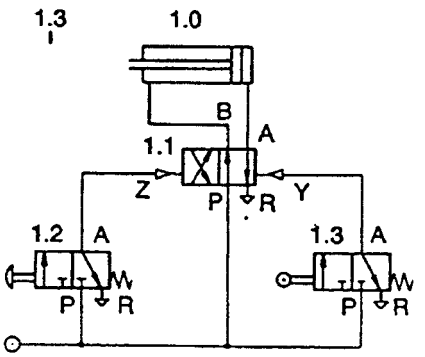
If valve 1.2 is operated, the 4/2-way valve (1.1) is reversed by the signal at Z. The cylinder travels out. It remains in this position until a signal from valve 1.3 again switches over valve 1.1 at Y.

Automatic Return of a Double-Acting Cylinder using a Limit Switch

Problem:

After reaching the forward end position, the piston of a double-acting cylinder is to return by itself, provided the valve (pushbutton) which initiates the advance movement is no longer actuated.

Solution:



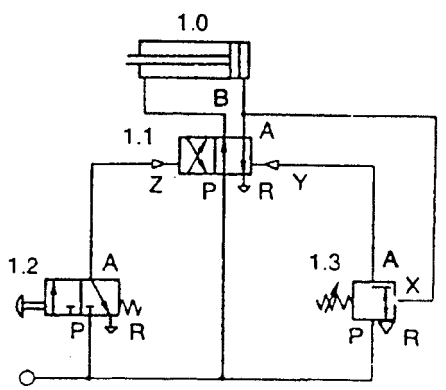
Control as in section ; valve 1.3, however, with roller plunger. A marker line (1.3) signifies that the valve is actuated by cylinder 1.0 in the forward end position.

Pressure-Dependent Control without Mechanical Checking of the End Position

Problem:

A double-acting cylinder is to be reversed by means of pressure. When a specific preset pressure has built up on the piston side, the cylinder must always travel back into the rear end position.

Solution:



Operation of valve 1.2 causes valve 1.1 to be switched over by means of compressed air. Cylinder 1.0 travels out. Compressed air is applied to valve 1.3 from the working line A. When the pressure has reached the preset value, valve 1.1 switches over.

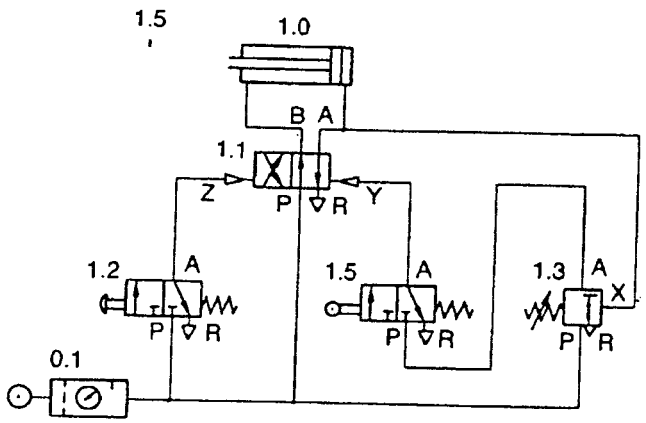
Valve 1.1 is switched over by valve 1.2. In this case, reversal is dependent not on travel but pressure through the sequence valve 1.3. If cylinder 1.0 is held in any intermediate position, reversal is effected before the piston reaches the forward end position (pressure build-up). For this reason, this type of control should be used only when there is no great safety requirement.

Pressure-Dependent Control with Additional Mechanical Checking of the End Position by means of a Limit Switch

Problem:

The piston rod of a double-acting cylinder is to move out when a manual starting signal is applied, and be reversed in the forward end position. The return movement may be made, however, only if the maximum pressure has built up in the cylinder when in the end position.

Solution:



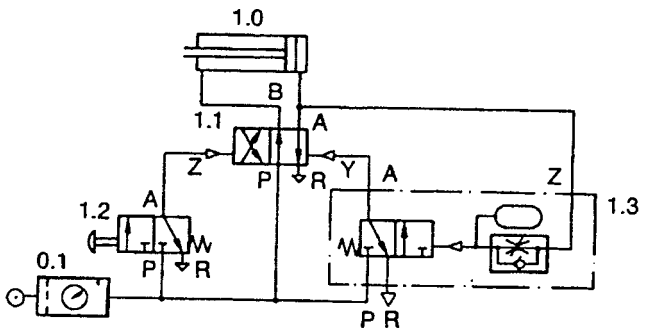
Operation of valve 1.2 causes valve 1.1 to be switched over by means of compressed air. Cylinder 1.0 travels against valve 1.5 in the forward end position. Sequence valve 1.3 is connected to working line A of the cylinder, and this valve transfers compressed air only after pressure has built up at valve 1.5. Valve 1.1 is thus switched over and cylinder 1.0 returns.

Time-Dependent Control without Mechanical Checking of the End Position

Problem:

After operating a pushbutton, the piston of a double-acting cylinder is to move out, remain stationary for a certain time in the forward end position, and subsequently travel back of its own accord.

Solution:



Operation of valve 1.2 causes valve 1.1 (Z) to switch over and the cylinder travels out. When the time has expired at A, a signal is applied to valve 1.1 (Y) through valve 1.3. The cylinder moves into the rear end position.

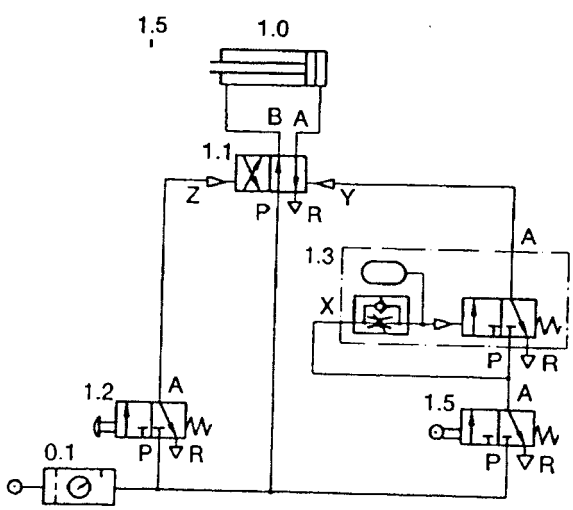
This control has the advantage of operating without limit switch and it is thus inexpensive, but at the expense of reliability. If the cylinder is held stationary in an intermediate position, valve 1.3 switches over after the preset time in spite of valve 1.1 and the piston of the cylinder travels into the rear end position.

Time-Dependent Control (Return Movement) with Mechanical Checking of the End Position using Limit Switch

Problem:

After operating a pushbutton, the piston of a double-acting cylinder is to travel out, remain stationary for a specific time in the forward end position, and subsequently return of its own accord.

Solution:



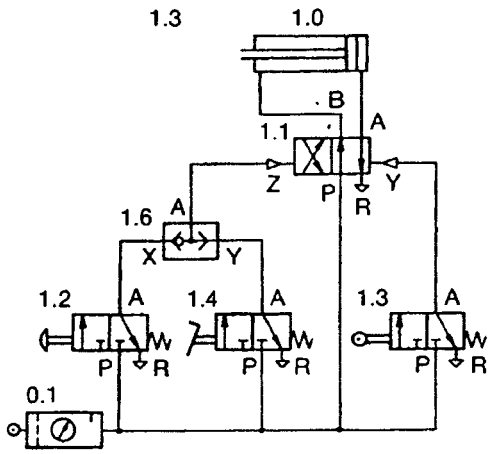
Operation of valve 1.2 causes valve 1.1 (Z) to switch over, and cylinder 1.0 travels out. On reaching the forward end position, it switches valve 1.5 over. The control line of the time delay valve 1.3 receives compressed air from valve 1.5 through the one-way flow control valve. Valve 1.3 switches over after the preset time. A signal is thus given to valve 1.1 (Y) for the return movement of cylinder 1.0.

Advance Movement Controlled from Two Different Points (Double-Acting Cylinder)

Problem:

The piston rod of a double-acting cylinder is to travel out if a signal is given from a valve with push-button or a valve with pedal. On reaching the front end position, the cylinder is to travel back into the initial position.

Solution:



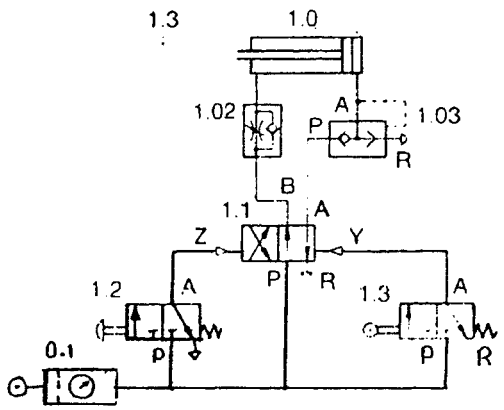
The signal for the advance movement of the cylinder is input through valve 1.2 or 1.4. Valve 1.3 switches the cylinder back into the initial position.

Slow Forward Movement – Rapid Return

Problem:

A double-acting cylinder is to travel out slowly and on reaching the end position return rapidly to its initial position.

Solution:



When valve 1.2 is operated, the piston of the cylinder travels out. The forward speed can be set on the one-way flow control valve 1.02. Switchover of valve 1.3 causes the piston to return to its initial position and the speed is increased by the quick exhaust valve 1.03.

Control with Additional Requirement

Problem:

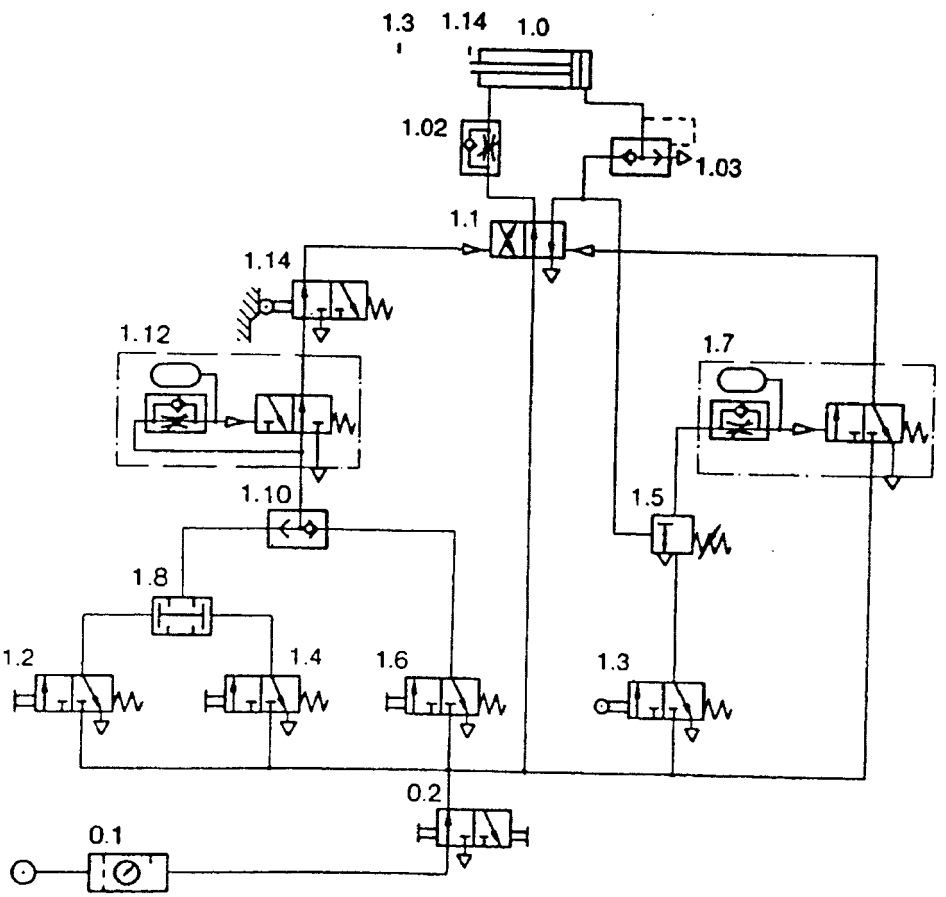
The advance movement of a double-acting cylinder is to be performed on the one hand by means of two pushbuttons, and on the other hand by means of one pushbutton. The cylinder is to travel out slowly.

Return movement is effected when
1. the cylinder has reached the forward end position,
2. a certain pressure has built up in the cylinder,
3. a certain time has expired.

The cylinder is to travel back to the rear end position as rapidly as possible.

Before restarting, the pushbuttons must be released and the cylinder must be in the rear end position.

Solution:



Chapter 5

Functional sequence - circuit diagram representation

PREPARED BY U TINT ZAW

Functional Sequence – Circuit Diagram Representation

The previous chapter 4 dealt with the most common basic circuits, a knowledge of which suffices to allow simple pneumatic controls to be built As soon as control functions become more complicated however, and larger systems have to be installed or even repaired, circuit diagrams and charts showing the functional sequence of the systems are very important for the maintenance personnel.

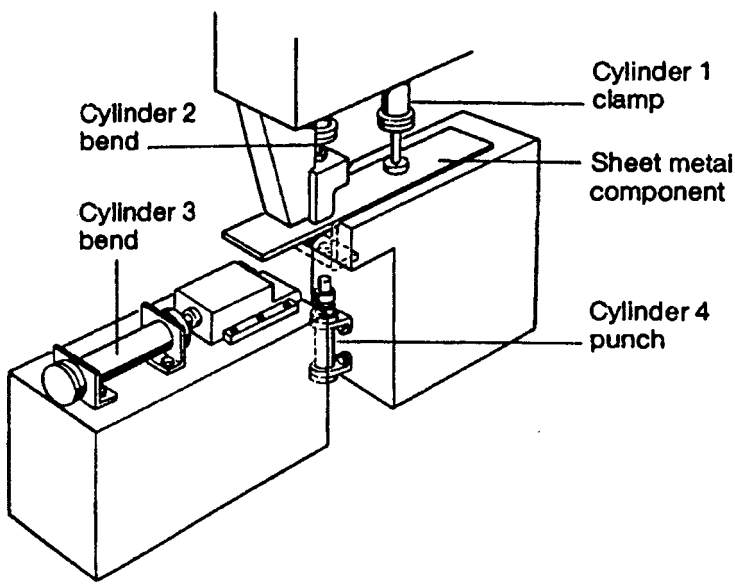
In most cases, charts exist but these do not correspond optimally to the functional sequences and they are not used by the maintenance personnel. The reason for this is a reluctance to use circuit diagrams which are not clear as well as incomprehensible representations of functional sequences. If uncertainty exists in reading symbols and hence complicated circuit diagrams, it is impossible to systematically build up pneumatic controls and, especially, to perform **"systematic fault tracing"**. A lot of time can be wasted in trying out, guessing, or searching unsystematically in circuit diagrams, functional sequences, or even in the completed control. Thus, it pays to get to know the pneumatic symbols, the layout of the circuit diagrams, and also the various possibilities for representing the functional sequences.

In this chapter, the various possibilities of representing functional sequences and circuit diagrams are given for the benefit of the maintenance engineer, using an example taken from practice.

Example: Bending and punching ficture

Sheet metal components are placed by hand in a holder. The sheet metal component is clamped by means of a pneumatic cylinder. Two other cylinders bend the component until another cylinder punches a hole.

Layout drawing:



Written Form of Representation

Listing in Chronological Order

Cylinder 1 clamps the sheet metal component
Cylinder 2 first bending operation
Cylinder 3 second bending operation
Cylinder 3 travels with bending die into initial position
Cylinder 4 punches 4 mm hole
Cylinder 4 travels into the initial position
Cylinder 2 travels with bending die in initial position
Cylinder 1 unclamps finished sheet metal component

Tabular Listing

Working step	Cylinder 1	Cylinder 2	Cylinder 3	Cylinder 4
1	OUT	–	–	–
2	–	OUT	–	–
3	–	–	OUT	–
4	–	–	IN	–
5	–	–	–	OUT
6	–	–	–	IN
7	–	IN	–	–
8	IN	–	–	–

OUT – travelling out to forward end position
IN – travelling in to rear end position

Vector Diagram

Cylinder 1 ⟶
Cylinder 2 ⟶
Cylinder 3 ⟶
Cylinder 3 ⟵
Cylinder 4 ⟶
Cylinder 4 ⟵
Cylinder 2 ⟵
Cylinder 1 ⟵

Travel out ⟶
Travel in ⟵

Abbreviated Notation

Cylinder 1 +
Cylinder 2 +
Cylinder 3 +
Cylinder 3 –
Cylinder 4 +
Cylinder 4 –
Cylinder 2 –
Cylinder 1 –

Travel out +
Travel in –

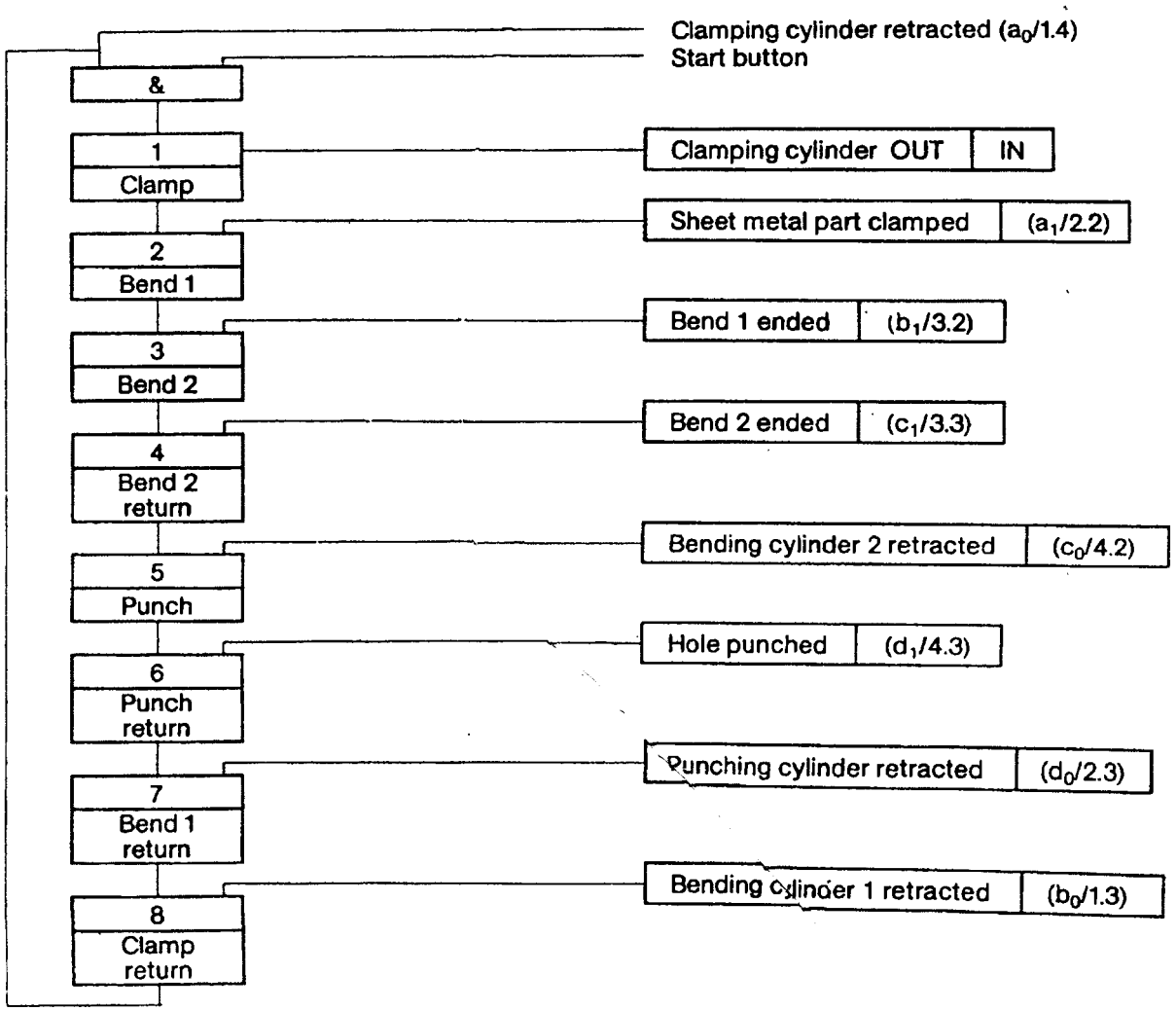
In the next written forms of representation (sequence chart, function chart), not only is the movement of the working element recorded, but the signal input and signal processing element are also included.

Sequence Chart

Sequence Chart

Step	Operation of valve	by	Reversal of reversing valve	Compressed air is in line	Reversal of actuator	Working element travels to		Comment
						forward end position	rear end position	
1	1.2 1.4	hand 1.0	0.2 (Y)	1	1.1 (Z)	1.0	–	–
2	2.2	1.0	–	1	2.1 (Z)	2.0	–	–
3	3.2	2.0	–	1	3.1 (Z)	3.0	–	–
4	3.3	3.0	0.1 (Z)	2	3.1 (Y)	–	3.0	–
5	4.2	3.0	–	2	4.1 (Z)	4.0	–	–
6	4.3	4.0	0.2 (Z) 0.1 (Y)	3	4.1 (Y)	–	4.0	–
7	2.3	4.0	–	3	2.1 (Y)	–	2.0	–
8	1.3	2.0	–	3	1.1 (Y)	–	1.0	–

Function Chart DIN 40 719, Draft April 75



Graphical Form of Representation (Diagrams)

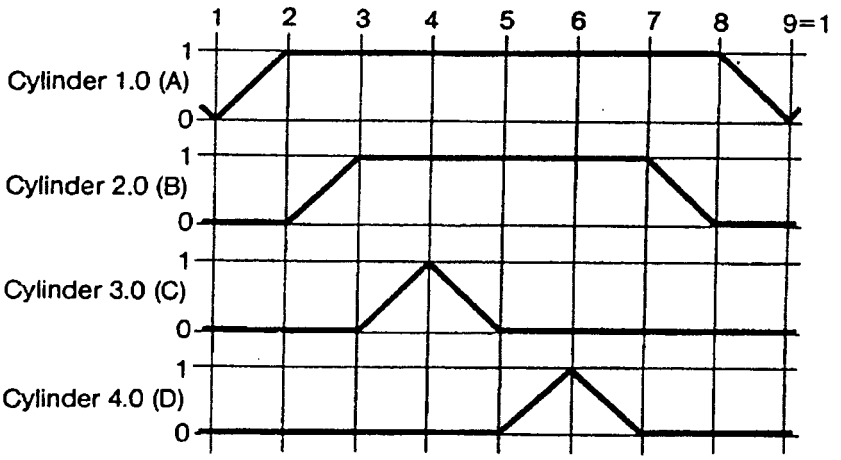
Motion Diagram

The sequences and states of the working elements (cylinders, assemblies) etc. are shown in the motion diagram. Two co-ordinates are used for this representation. In one coordinate, the displacement (stroke of the working element) is entered, and in the other the steps **(displacement-step diagram.**

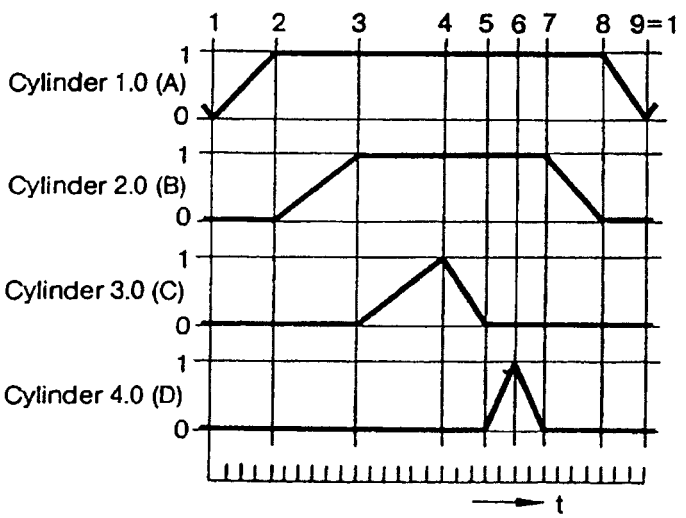
In addition to this diagram, it is also possible to record the time **(displacement-time diagram).** These forms of representation of functional sequences are contained in the VDI Recommendations 3260.

Diagrams for the example: Bending and stamping fixture.

Displacement-step diagram



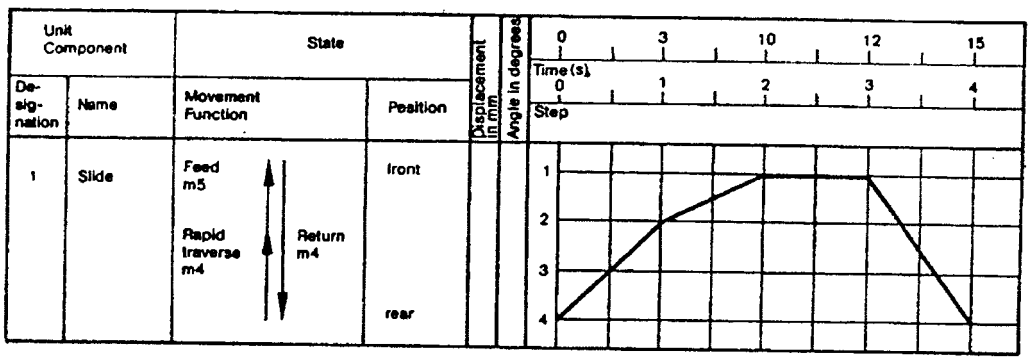
Displacement-time diagram



These diagrams allow the sequence of motions of the machines to be easily recognised.

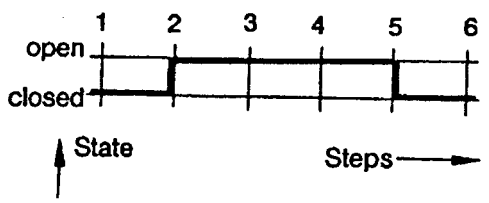
The operating sequence can also be represented in terms of pressure, power, and angle.

Displacement-step diagram in accordance with VDI 3260



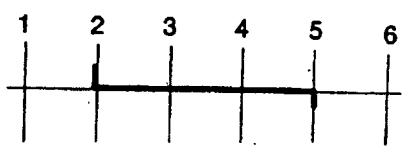
Control Diagram

The switched states of the signal elements and control elements over the steps are drawn in the control diagram. The switching time is neglected here. Only the open or closed state of a switch is of importance.



In the above example, a limit switch opens at step 2 and closes again at step 5.

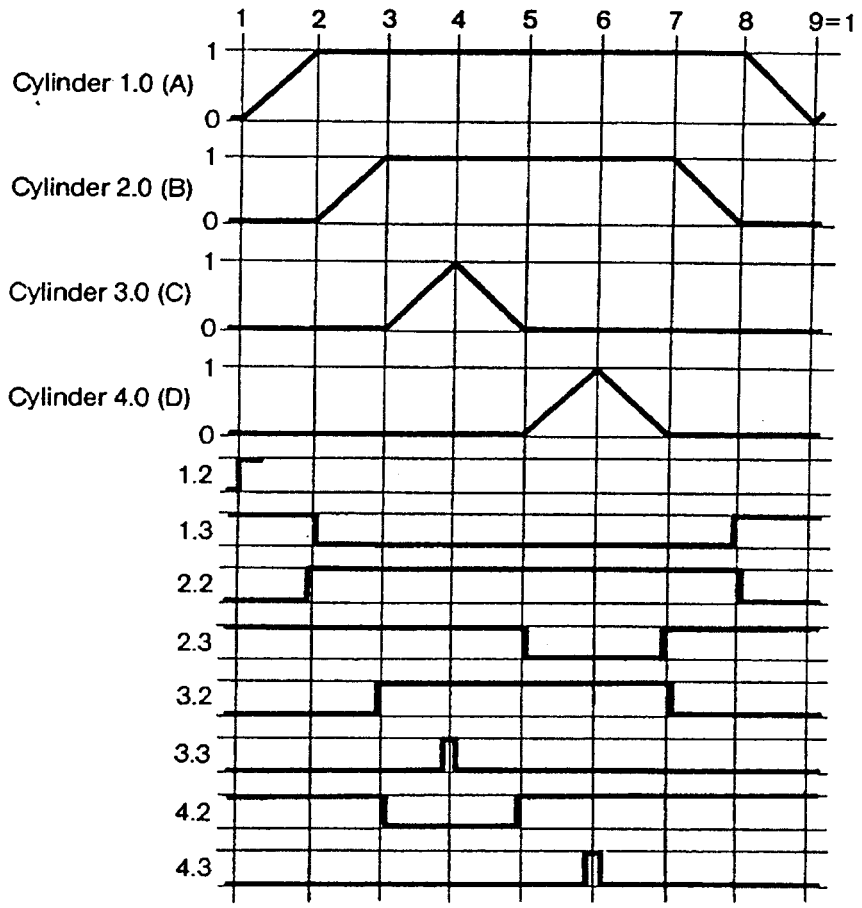
The control diagram can also be represented in such a way that the state is drawn only on the line.



The motion and control diagrams each represent a functional sequence for a particular group of components. For this reason, the expression "function diagram" is also used frequently.

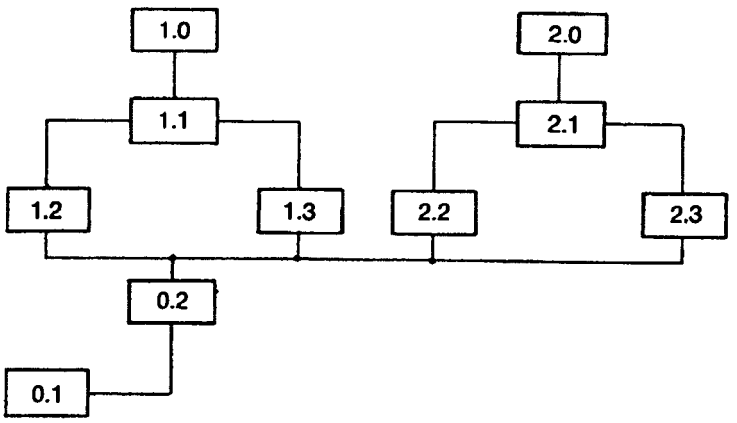
In most cases, the motion diagram and the control diagram are drawn together as a single diagram which is known as the complete function diagram.

The function diagram is shown here for the bending and punching fixture example.



Circuit Diagram Representation

Designations in the Circuit Diagram (Designation of Elements)



Working elements (cylinder, air motor, unit etc)

Actuating elements

Signal elements

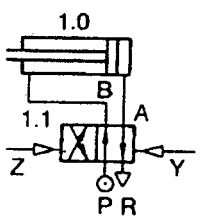
Supply elements (service unit, shut-off valve, reversing valve)

A working element and associated valves is considered to be control chain number 1, 2, etc. The first digit in the designation of the element thus indicates to which control chain the element belongs.

The digit after the point (1.2, 1.3, 1.6, 2.3) specifies the element concerned (see drawing above).

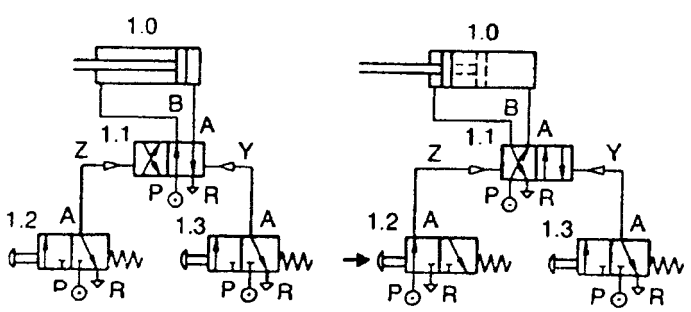
1.0, 2.0, 3.0 ... **Working elements** (cylinder, unit etc.)
1.1, 2.1, 3.1 ... **Actuating elements**

Example:



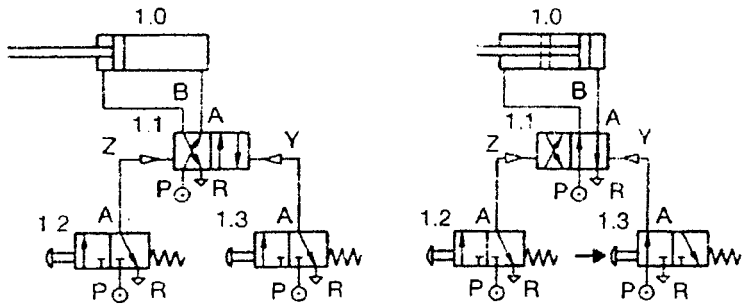
1.2, 1.4, 2.2, 2.4, 3.2 ... **Signal elements:** These signal elements have an even final digit and they normally affect the **advance movement** of the working element.

Example:



1.3, 1.5, 2.3, 2.5, 3.3 . . . **Signal elements:** These signal elements have an odd final number and normally affect the **return movement** of the working element.

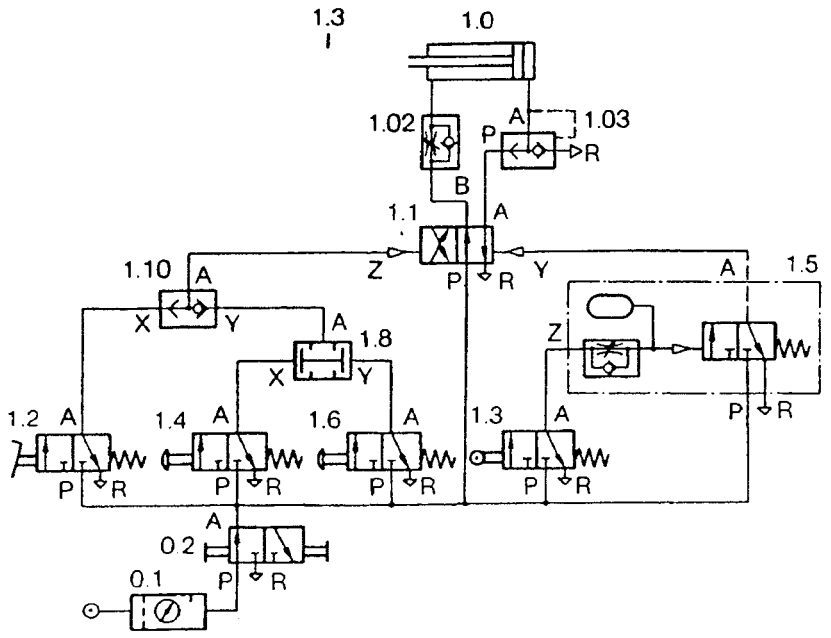
Example:



0.1, 0.2, 0.3 . . . **Supply elements:** (Service unit, shut-off valve, reversing valve). These elements affect all control chains.

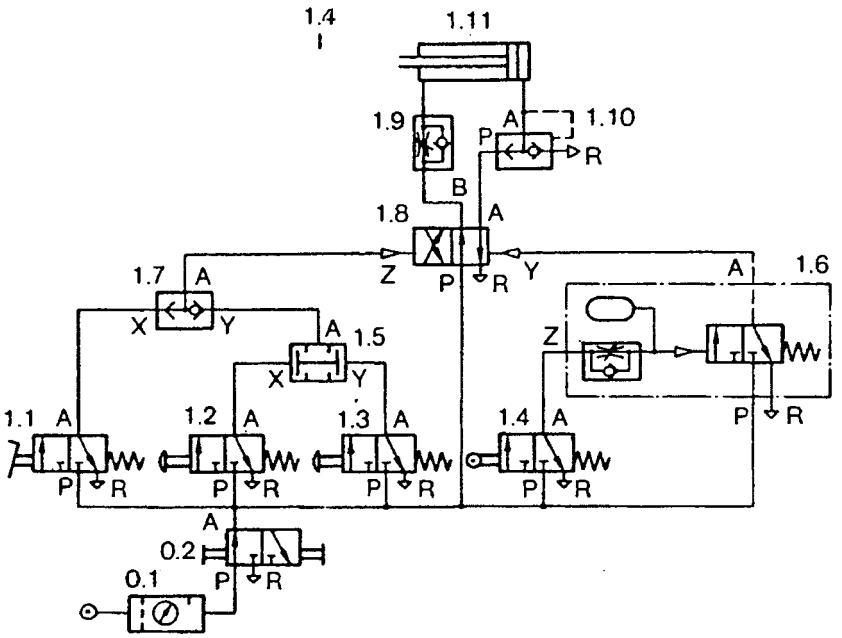
1.02, 1.03, 2.02 . . . **Auxiliary devices:** (one-way control valve, restrictor, quick exhaust valve).

Example:



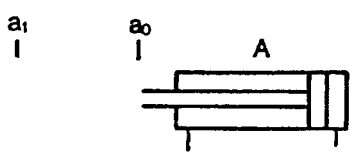
Another type of designation for the circuit diagram is given in the **VDI Recommendations 3226.** With this type of designation, the various components such as working element, actuating element, signal element, supply element are not provided with a constant number, but consecutive numbering is used. The circuit diagram below shows this type of numbering.

Designation in accordance with VDI Recommendations 3226



Designation using Alphabetic Characters

This type of designation is often used for developing circuit diagrams, but it is also used frequently in the circuit diagram instead of numerical designation. With this method, the working elements are given capital letters and signal elements are given small letters.



A, B, C ..... allocated to the working elements

a_1, b_1, c_1 ..... allocated to the signal elements in the forward end position

a_0, b_0, c_0 ..... allocated to the signal elements in the rear end position

As in electrical engineering, it is also possible to use a combination of numbers and letters.

Representation of Devices

All devices should be shown in the circuit diagram in the initial position of the control. If this is not possible, or if an exception is made to this, it is necessary to add a note.

If valves are drawn in the normally open condition, this must be indicated e.g. by means of an arrow, or in the case of a limit switch, by drawing the cam.

Definition of positions in accordance with DIN 24 300

Normal position:

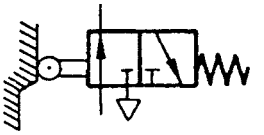
Position of the moving parts of the valve when the valve is not connected. (For valves with reset.)

Initial position:

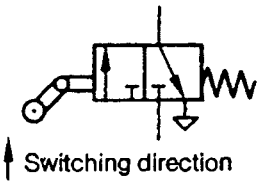
Position of the moving parts of the valve after installing in a system and switching on the mains pressure and with which the intended operating cycle begins.

Example:

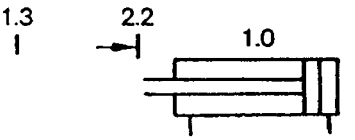
Designation of a signal element (limit switch) which is normally closed and drawn in the circuit diagram in the operated position.



Valves with idle return rollers can transmit a signal in one direction only.



The switching direction must be drawn in the circuit diagrams.



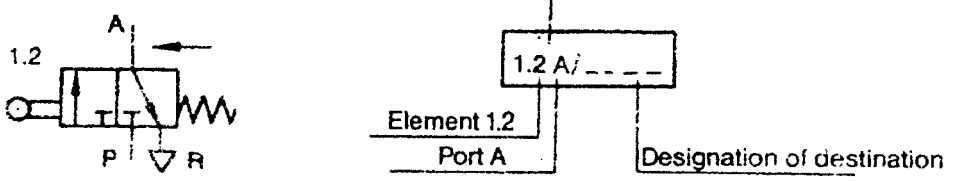
The marking lines specify: In the forward end position, signal element 1.3 is switched and on the return stroke of the cylinder, signal element 2.2. The arrow indicates that the valve is of the idle return roller type and switches only on the return stroke.

Pipeline and Pipeline Designation

Pipelines can be provided with pipeline designations in the circuit diagram and in the assembled installation. It is advisable to use a coded designation containing the connection and the destination. The connection is designated by the number of the element and also the connection.

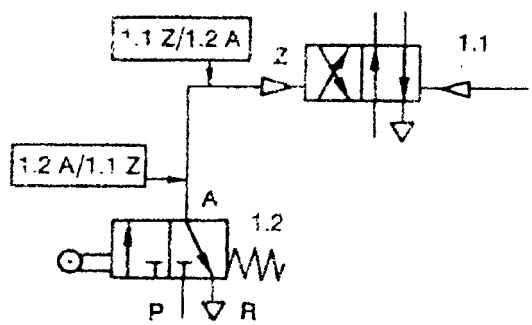
Pipelines should where possible be drawn as straight lines without crossovers. Working lines are drawn as full lines, and control lines are drawn broken. In complex controls especially, it is however easier and clearer to draw the control lines as full lines also.

Connectors and pipelines can be localized by adding the connection designation of the element to the designation of the element itself (e.g. 1.2 P: Pressure connection of element 1.2, 1.2 A: Working connection of element 1.2).



The designation of the destination specifies where the pipeline goes to, e.g. to element 1.1 and control connection Z.

to element 1.2 [1.2 A/1.1 Z] to element 1.1 [1.1 Z/1.2 A]



Chapter 6

Reading Circuit diagrams

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Reading Circuit Diagrams

In order to be able to read circuit diagrams properly, it is important to know the meaning of the Recommendations and Standards for circuit diagram construction, designation of circuit diagrams and charts, functional sequences. A summary of the Recommendations and Standards has been given in chapter 5.

Graphical representation (displacement-step diagram, displacement-time diagram) - VDI 3226, VDI 3260, DIN 19 226.

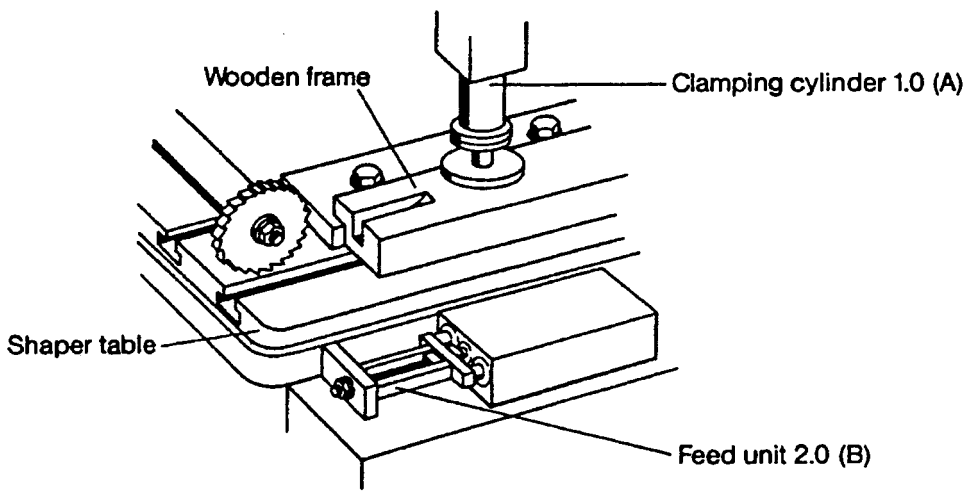
The various forms a control can take are shown by means of the following examples. Systematic reading of circuit diagrams and drawing functional sequences should be practised with these examples.

Example: Hand-Lever Shaper

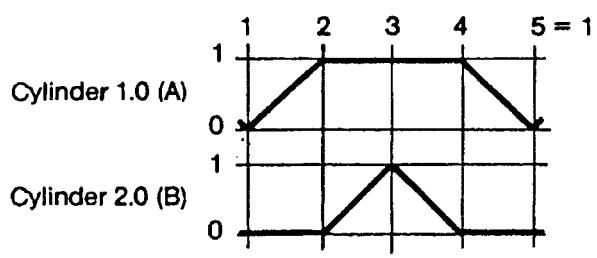
Groove Cutting

Grooves are to be cut in wooden frames on a shaper. The wooden frame is clamped with a pneumatic cylinder. The feed of the shaper table is performed by a pneumatic-hydraulic feed unit.

Layout drawing

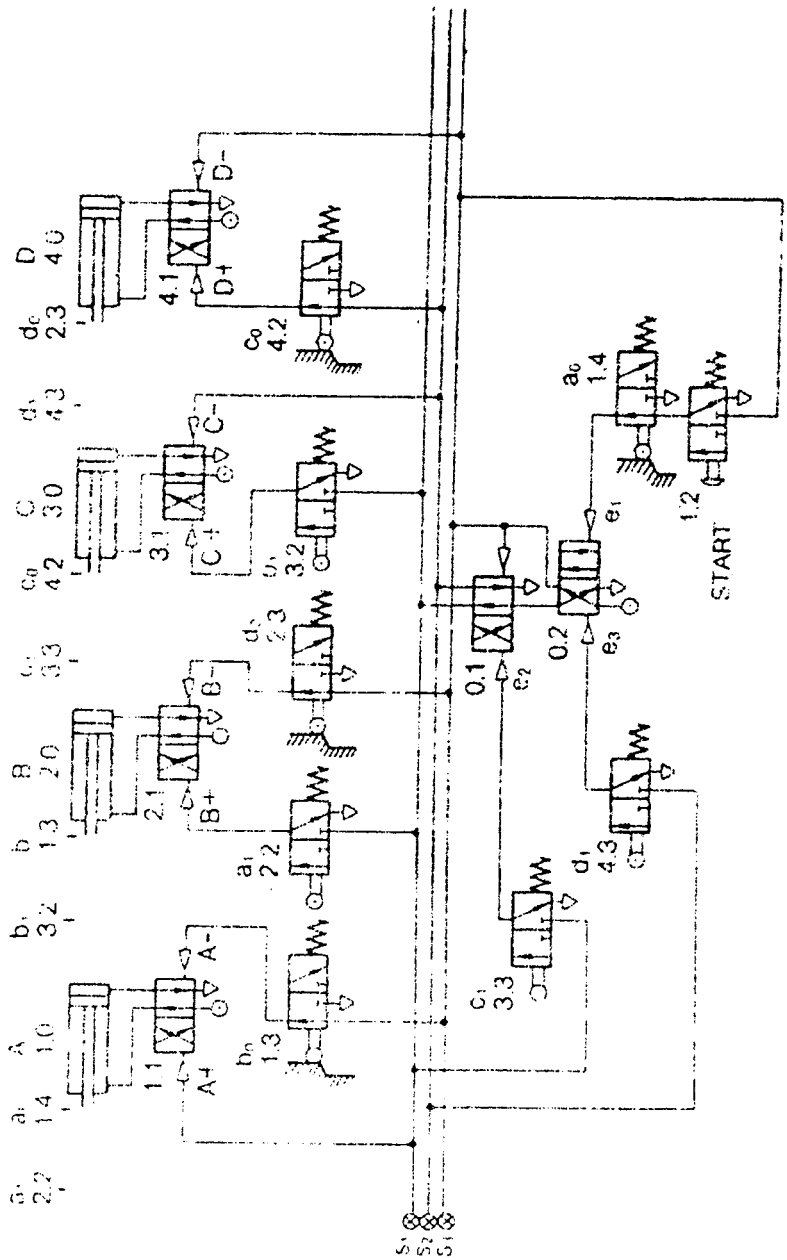


Displacement-step diagram



System Circuit Diagram

Example: Bending and punching fixture



Cascade control

With this cascade control, two or several reversing valves can be included connected in series. Valves with roller actuation are still used as limit switches.

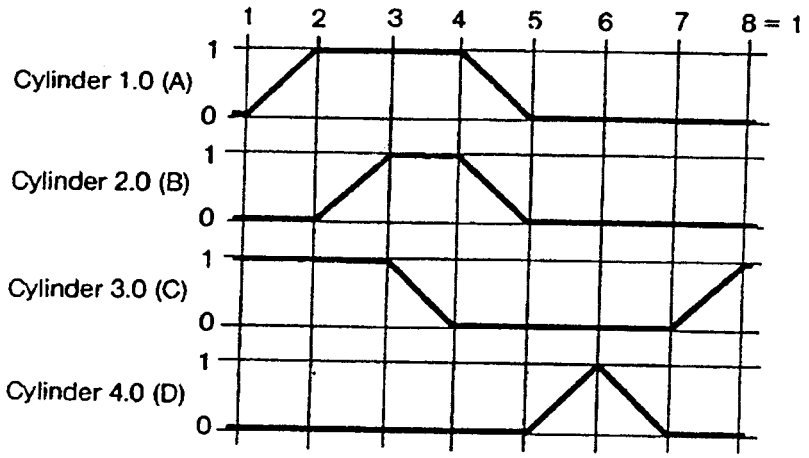
Control sequence

The control is started through valve 1.2, valve 0.2 switches over at Y, compressed air flows in line 1 Cylinder 1.0 (A) travels out, operates limit switch 2.2 (a_1), and cylinder 2.0 (B) is thus supplied with compressed air through valve 2.1. Cylinder 2.0 (B) travels out, operates limit switch 3.3 (b_1) the signal from this limit switch reverses valve 3.1, and cylinder 3.0 (C) travels back. In the rear end position of cylinder 3.0 (C) limit switch 1.3/2.3 (c_0) is operated, and reversing valve 0.1 is controlled at Z with this signal. Air line 1 is then exhausted, and air flows in line 2. By switching over to line 2, cylinders 1.0 (A) and 2.0 (B) return to their initial positions. Limit switches 4.2 (a_0) and 4.4 (b_0) are then contacted and switched. These cause compressed air to be supplied to cylinder 4.0 (D) through valve 4.1. Cylinder 4.0 (D) travels out, and switches limit switch 4.3 (d_1). This limit switch causes reversing valve 0.2 to switch at Z and the entire cascade returns to the starting position. Compressed air is contained in line 3, line 2 is exhausted, and thus cylinder 4.0 (D) can travel back. Operation of 3.2 (d_0)by cylinder 4.0 (D) causes cylinder 3.0 (C) to travel out again. The control is now in its starting position again.

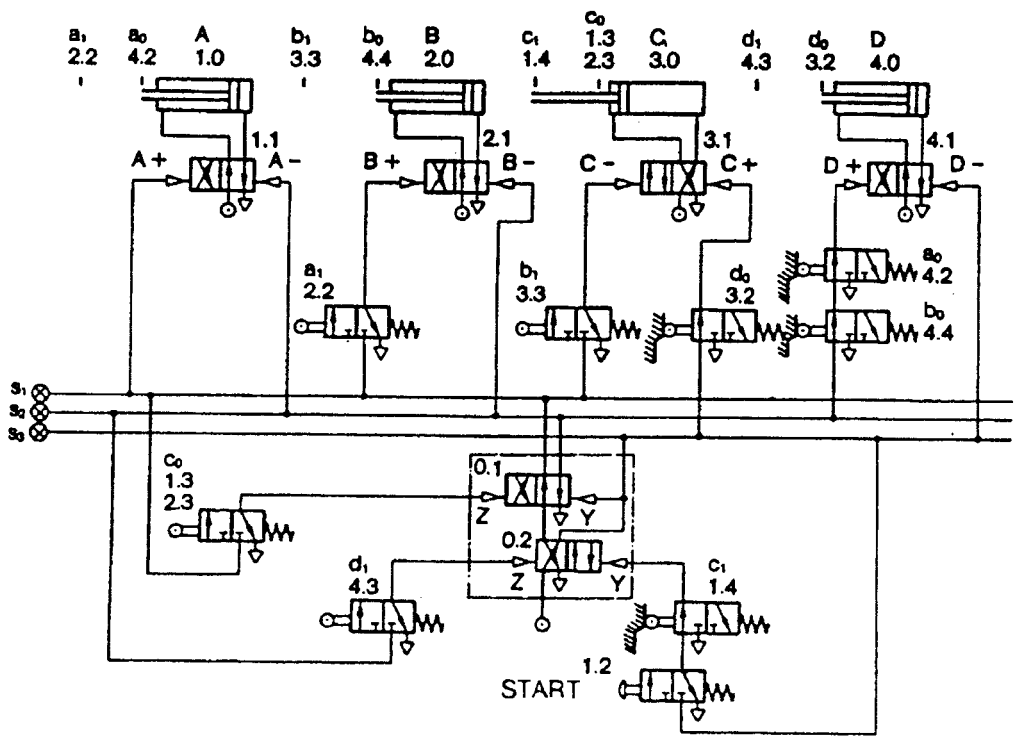
Sequence chart

Step	Operation of valve	by	Reversal of reversing valve	Compressed air is in line	Reversal of actuator	Working element travels to		comment
						forward end position	rear end position	
1	1.2 1.4	hand 3.0	0.2 (Y)	1	1.1 (Z)	1.0	–	–
2	2.2	1.0	–	1	2.1 (Z)	2.0	–	–
3	3.3	2.0	–	1	3.1 (Z)	–	3.0	–
4	1.3/2.3	3.0	0.1 (Z)	2	1.1 (Y) 2.1 (Y)	–	1.0 2.0	–
5	4.2 4.4	1.0 2.0	–	2	4.1 (Z)	4.0	–	–
6	4.3	4.0	0.2 (Z) 0.1 (Y)	3	4.1 (Y)	–	4.0	–
7	3.2	4.0	–	3	3.1 (Y)	3.0	–	–

Displacement-step diagram



Circuit diagram: Lathe (semi-automatic) – cascade control



Sequence chart

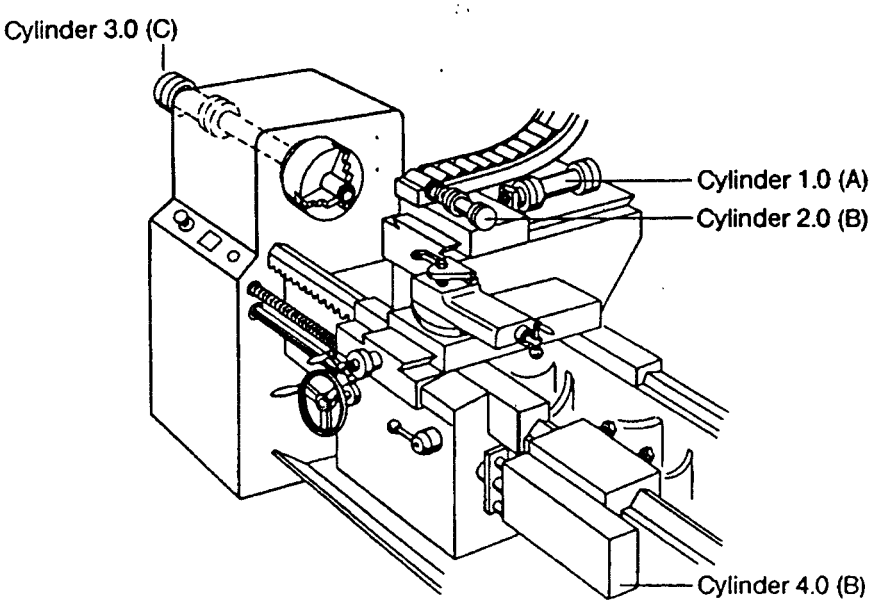
Step	Operation of valve	by	Reversal of reversing valve	Compressed air 's in line	Reversal of actuator	Working element travels to		Comment
						forward end position	rear end position	
1	1.2 1.4	hand 1.0	0.1 (Y)	1	1.1 (Z)	1.0	–	–
2	2.2	1.0	–	1	2.1 (Z)	2.0	–	–
3	3.2	2.0	–	1	3.1 (Z)	3.0	–	–
4	2.3/3.3	3.0	0.1 (Z)	2	2.1 (Y) 3.1 (Y)	–	2.0 3.0	–
5	1.3 1.5	2.0 3.0	–	2	1.1 (Y)	–	1.0	–

Example: Lathe (Semi-Automatic)

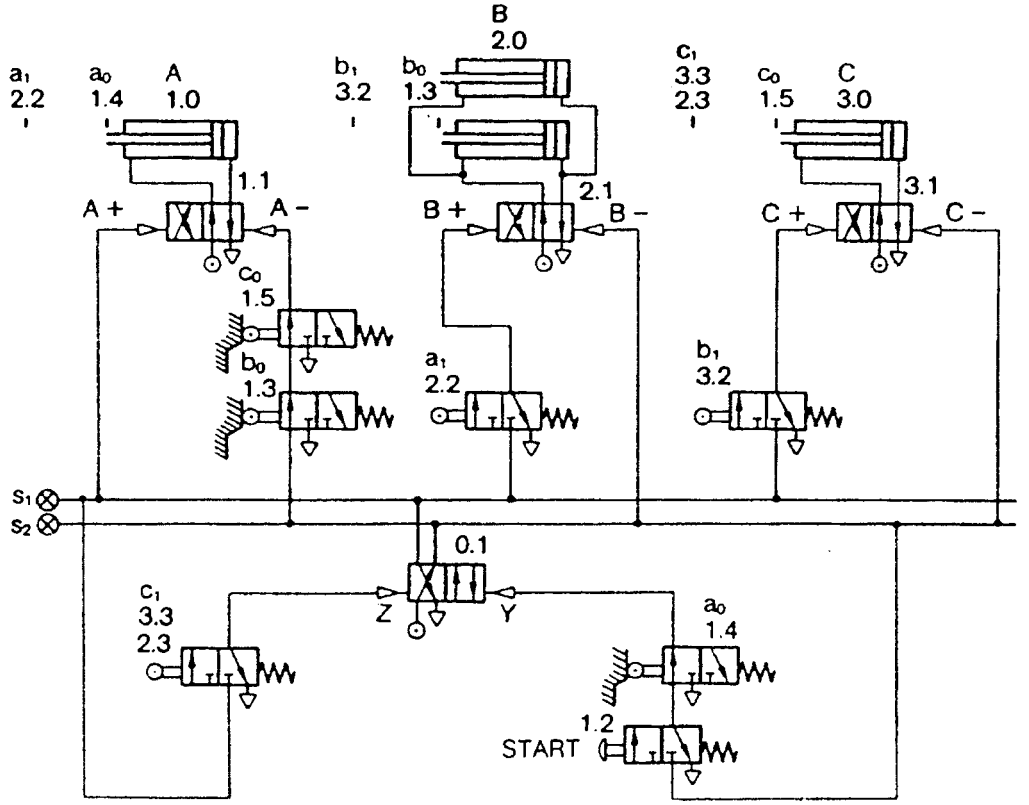
Machining of bushings (inside diameter)

The bushings are fed to the lathe from a slide. Cylinder 1.0 (A) moves the carriage into position. Cylinder 2.0 (B) pushes the part into the collet chuck. Cylinder 3.0 (C) clamps the bushing. Feed unit 4.0 (D) machines the inside diameter of the bushing. The part is unclamped and removed by hand. A new start signal causes a new cycle to be performed.

Layout drawing



Circuit diagram: Riveting machine



In this control, only limit switches with roller lever are used. Limit switches with idle return rollers are not used here for signal cut-out, but instead a reversing valve (4/2-way valve with memory function) is used.

Control sequence

The control is supplied with compressed air through reversing valve 0.1 via line 2. The start signal from valve 1.2 causes valve 0.1 to switch over at Y, and air flows through line 1. This switchover to line 1 causes valve 1.1 to switch over at Z, and cylinder 1.0 (A) travels into the forward end position. Here it operates limit switch 2.2 (a_1) which causes valve 2.1 to be switched over at Z. Cylinder 2.0 (B) travels into the forward end position. Limit switch 3.2 (b_1) is operated when the piston is in the extended position. and this means that valve 3.1 is switched over at Z and cylinder 3.0 (C) travels out. By travelling out, cylinder 3.0 (C) causes 2.3/3.3 (c_1) to be operated in the forward end position and this limit switch causes the reversing valve 0.1 to return to its initial position through Z.

Air thus flows through line 2 and valves 2.1 and 3.1 (at Y) cause cylinders 2.0 (B) and 3.0 (C) to travel into the rear end position. Cylinder 2.0 (B) travels onto limit switch 1.3 (b_0), and cylinder 3.0 (C) onto limit switch 1.5 ($_0$). This means that when both switches are pressed, cylinder 1.0 (A) will also return to its initial position via valve 1.1 which has switched over at Y. The control is now in the starting position.

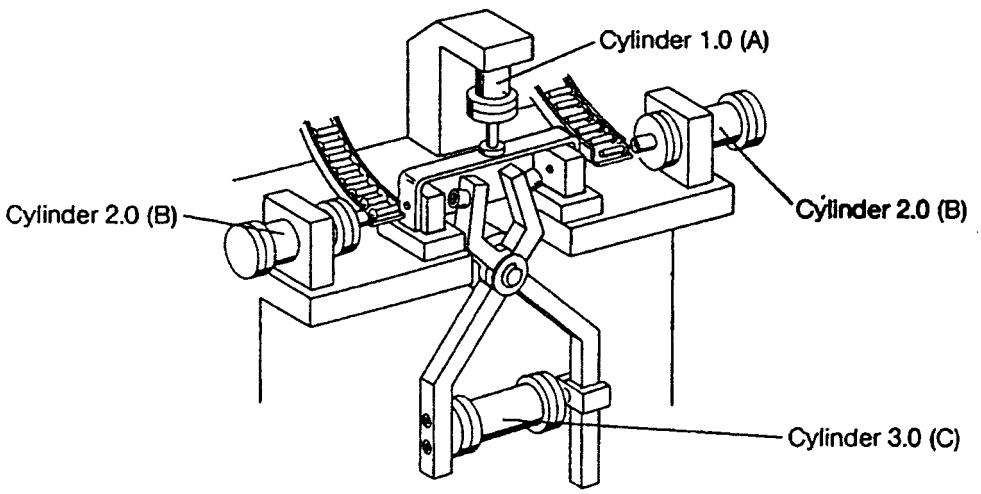
Example: Rivetting Machine

Rivetting of brackets

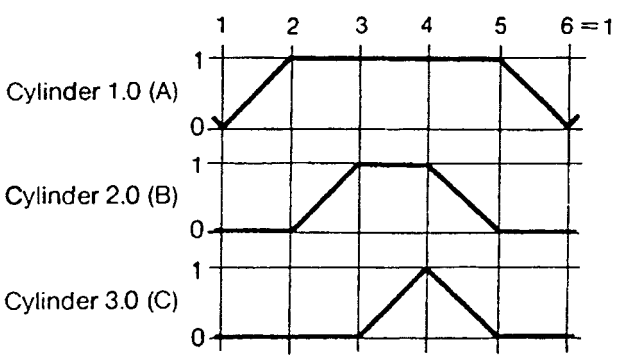
The parts are loaded by hand. Cylinder 1.0 (A) clamps. The two cylinders 2.0 (B) push the rivets in and hold them firmly.

Cylinder 3.0 (C) produces the 2nd half-round head. The completed parts can be removed by hand.

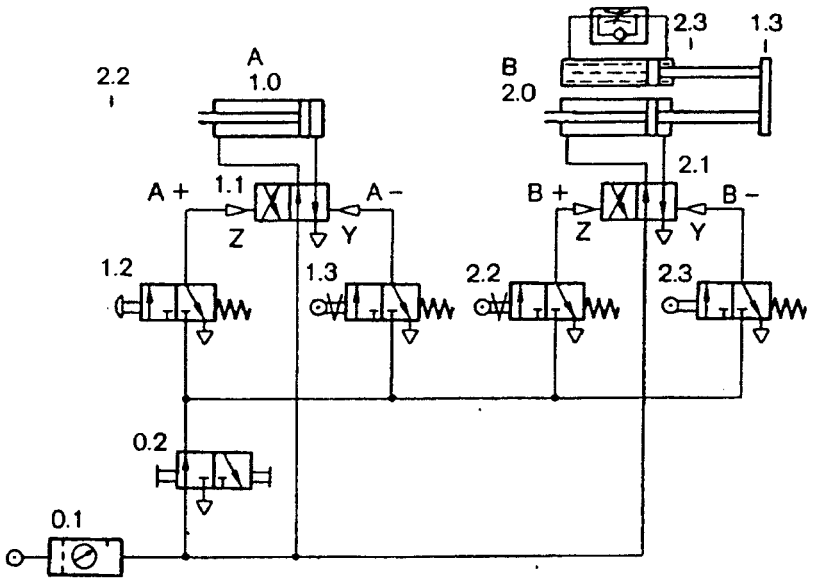
Layout drawing



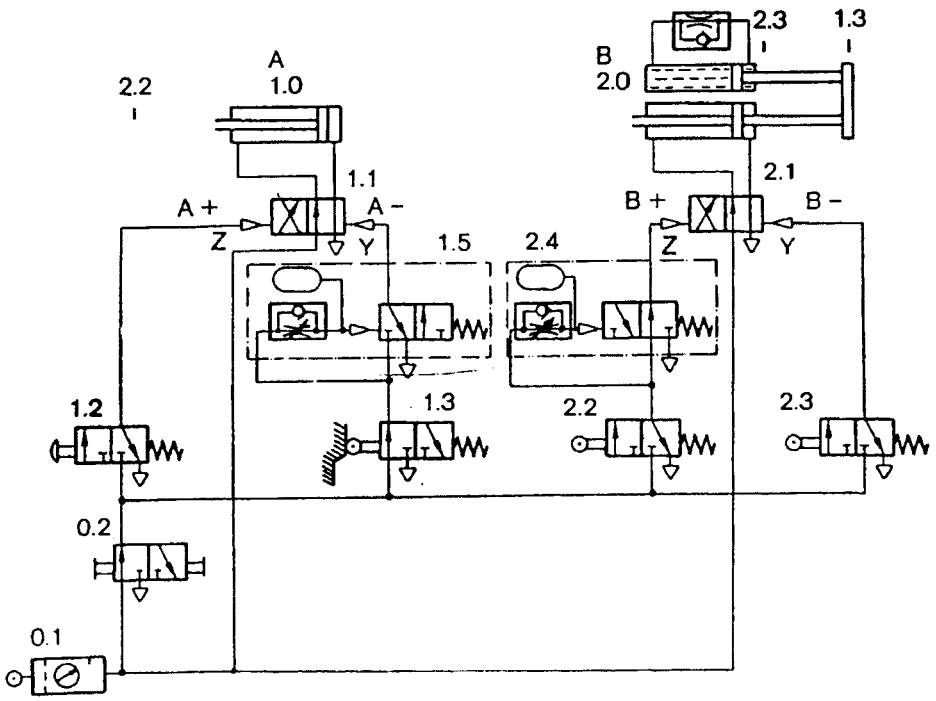
Displacement-step diagram



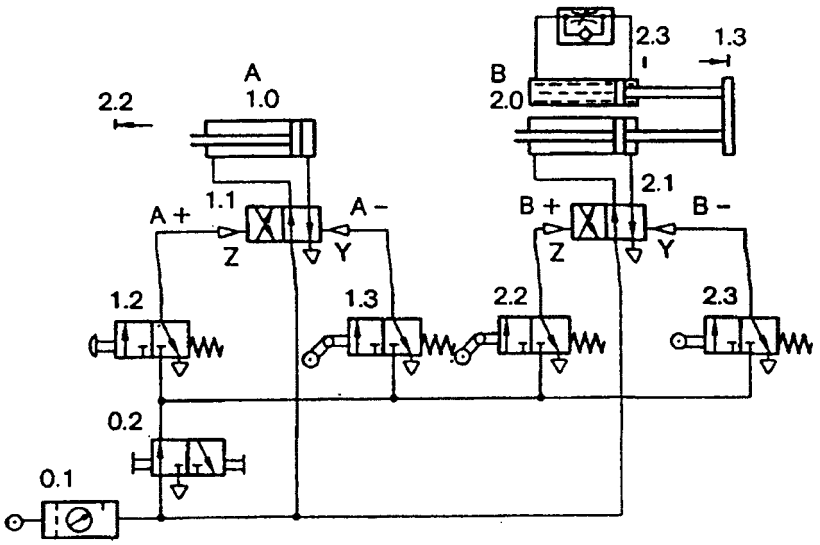
Circuit diagram: Hand-lever shaper (over-centre device, momentary signal generator)



Circuit diagram: Hand-lever shaper (time delay valve)



Circuit diagram: Hand-lever shaper (idle return roller)



Control sequence

The conditioned compressed air flows through service unit 0.1 and valve 0.2 to all other valves. If the start button 1.2 is operated, valve 1.1 switches over at Z, cylinder 1.0 (A) travels into the forward end position and clamps the wooden frame. On the advance movement of the cylinder 1.0 (A), limit switch 2.2 is pressed shortly before the forward end position is reached. Compressed air is applied to valve 2.1 at Z, and the valve switches over. Feed unit 2.0 (B) travels out. The shaper table is moved slowly and the groove is cut into the wooden frame. Limit switch 2.3 is located at the forward end position of the feed unit 2.0 (B), it is pressed and it causes the feed unit to return by acting on valve 2.1 at Y. Operation of limit switch 1.3 in the rear end position of the feed unit 2.0 (B) causes valve 1.1 to be switched over at Y and cylinder 1.0 (A).unclamps the wooden frame.

Sequence chart

Step	Operation of valve	by	Reversal of reversing valve	Compressed air is in line	Reversal of actuator	Working element travels to		Comment
						forward end position	rear end position	
1	1.2	hand	–	–	1.1 (Z)	1.0	–	–
2	2.2	1.0	–	–	2.1 (Z)	2.0	–	slow feed unit
3	2.3	2.0	–	–	2.1 (Y)	–	2.0	–
4	1.3	2.0	–	–	1.1 (Y)	–	1.0	–

Constructing the circuit diagram for coordinated motion controls

If the motion diagram and auxiliary conditions have been clearly defined, drawing of the circuit diagram can commence. Representation and drawing layout were described in detail in Section The circuit is now built up in accordance with this pattern.

This design, and hence also the basic pattern for constructing the circuit diagram, depends on the type of signal cut-out used.

Where simpler types of controls are concerned, and particularly where the disadvantages of cutting out signals by means of idle return rollers can be accepted, the use of valves controlled by idle return rollers can be justified.

In all other cases, signal cut-out by means of bi-stable valves should be incorporated.

Incorporation of these valves can be effected in different ways. First, it will be shown how this type of cut-out can be incorporated by the intuitive method, and then one of the available methods will be applied which always ensures positive and reliable cut-out by means of bi-stable valves, even where the control is elaborate.

The advantages and disadvantages will be discussed in detail later in the text. At this point, it is sufficient to say that this method for constructing a circuit diagram is certainly the easiest to learn for controls where signal cut-out is effected by means of bi-stable valves. The same basic thinking is also behind the design of a stepper circuit.

Another point to be observed is in the inclusion of auxiliary conditions in a control. It is expedient to consider and include these conditions only when the basic circuit for a function has been completed. These requirements should then be incorporated singly, i.e the circuit diagram should be expanded step by step. This is the only way to ensure that the circuit retains its overall clarity, even where elaborate controls are concerned.

The exercises and examples given in Section should assist in a proper understanding of the methods and tips listed here. At the same time, these examples will allow some important circuitry tricks to be learned.

Naturally, most control engineering problems have several solutions each of which is frequently as good as the next. For the sake of clarity, only those solutions will be given in the following which are most important to know and which are considered most suitable from the point of view of learning success.