FLUID POWER

CIRCUITS – PART 2

TUTORIAL – CONTROL OF FLUID POWER SYSTEMS

This work covers part of outcome 3 of the Edexcel standard module:

UNIT 21746P APPLIED PNEUMATICS AND HYDRAULICS

The material needed for outcome 3 is very extensive so the tutorial is presented as a series.

OUTCOME 3 Investigate pneumatic and hydraulic circuits	• Design and draw a circuit for either pneumatic or hydraulic multi-actuator sequential operation, including emergency stop functions. • Design and draw either a pneumatic or hydraulic rotary actuation circuit illustrating speed control in both directions.
	• Design and draw either an 'electro-pneumatic' or 'electro-hydraulic' circuit arrangement.
	• Design and draw an emergency 'fail safe' circuit for either a pneumatic or hydraulic application.

This series of tutorials provides extends the work from outcome 2 to the construction of complete circuits.

- Define ON/OFF control.
- Explain sequential operation.
- Explain opposing signals.
- Describe methods of overcoming opposing signals.
- Describe the Cascade system of control.
- Design circuits for sequential control.

If you have access to simulation software such as PneSim Pro® you can construct the circuits in this exercise and simulate them to see how they work.

1. ON – OFF CONTROL

Many automatic processes only require cylinders and motors to operate between fixed limits. To do this, the air or oil must be switched ***on and off*** by the control valve. Usually the actuators act in a fixed sequence in order to do the required task.

The control valves are ordinary 2 or 3 position directional control valves that will supply fluid fully on in either direction or turn it off. The sensors may be any form of limit switch or proximity detector already covered in previous notes.

1.1 SEQUENCES

Many systems used on production lines use two or more actuators that must perform a repeated cycle of operations. An example of this might be a simple pick and place robot. The operations are carried out between fixed limits so on/off control is suitable but the problem is how to make the valves switch on and off in the required sequence. This is SEQUENTIAL CONTROL.

A programme to do sequential programmes mayuse OPEN or CLOSED LOOP control.

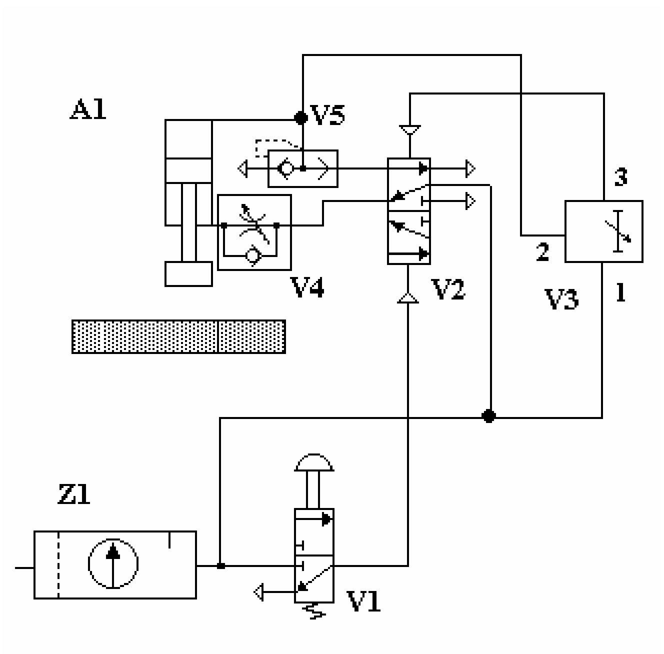


Figure 1

An open loop programme uses no feedback and the sequence may be done by using timers. The circuit shows an example of open loop control. When V1 is pressed the DCV V2 operates and cylinder A1 goes down. Pressure from the cylinder port activates port 2 on the timer V2 and after a preset time delay, pressure appears at port 3 and moves the DCV back and raises the cylinder. No position sensing is used to determine if the cylinder actually went down.

A closed loop programme uses the feedback from the hardware being controlled so that each step is initiated by a feedback signal. If something became stuck, the sequence would halt.

The circuit below is a closed loop circuit. When pilot air is supplied to valve A+, cylinder A extends (on) to the a+ position and pilot air is obtained from the valve at the a+ position and supplied to Valve B+ and so on. Study the circuit and convince yourself that the sequence performed is:

A+ B+ C+ A- B- C-

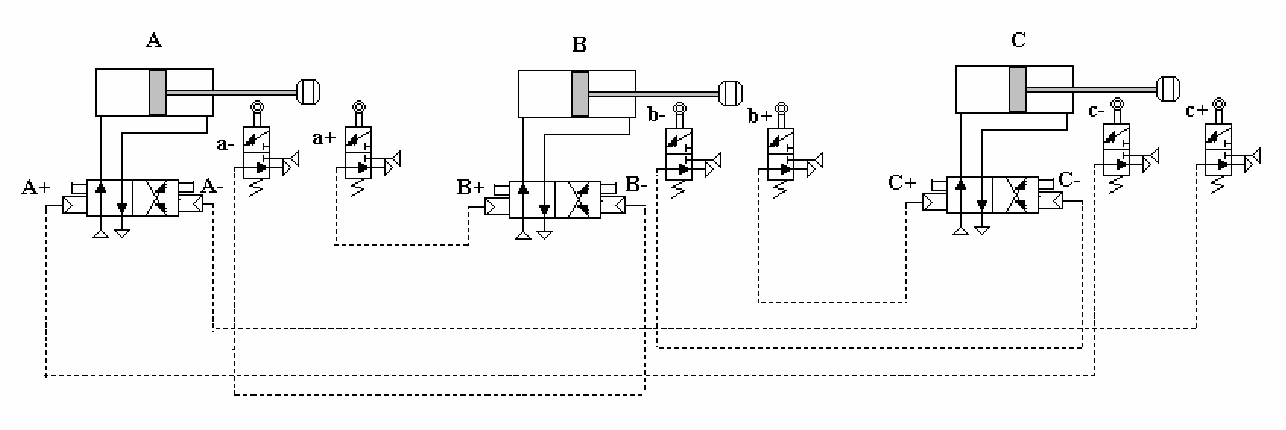


Figure 2

The sequences that can be made in this way are limited and only work if the actuators are switched off in the same order that they are switched on, otherwise we get pilot pressure to both sides of the same DCV at the same time. When this happens a standard valve will not move and the sequence stops. Consider the circuit below. Starting with A+ we get B+ then C+. At this point the sequence will stop as the feedback goes from c+ to B- and because air pressure is applied to both B+ and B- at the same time the valve will not move.

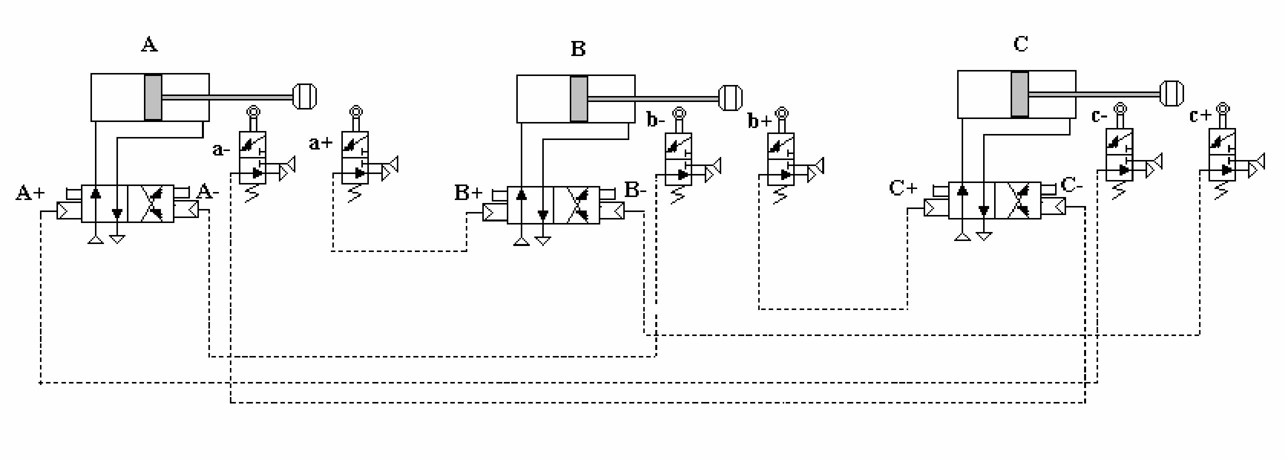


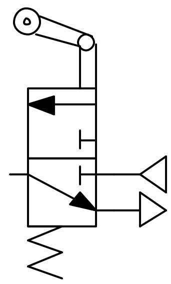
Figure 3

When opposing signals occur there are three ways overcome the problem.

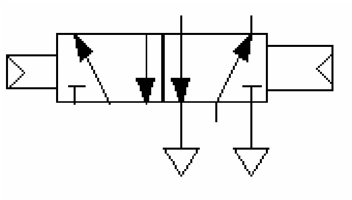
i. ***Uni-directional Roller.*** The cylinder passes over the roller and produces a pulse of pressure in one direction only. The pulse is sufficient to operate the pilot valve but no trapped pressure is left behind. The mechanism depressing the roller must pass right over it and not stop on top of it.

ii. ***Unequal pressure pilot valves.*** A pilot valve may be made to operate in one direction when the same pressure is applied to both ends because the two pilots operate at different pressures.

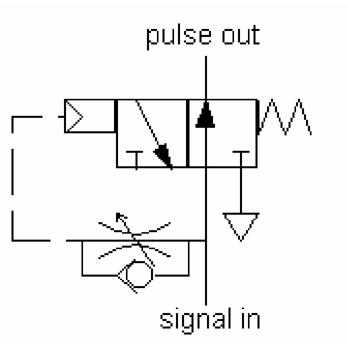
iii. ***Pulse generators.*** These generate a short pulse to the pilot line when a signal pressure is applied thus leaving the pilot line free of trapped air.



Uni- Directional Roller



Unequal pilot



Pulse generator

Figure 4

SELF ASSESSMENT EXERCISE No.1

Deduce the sequence for the circuit below and identify where opposing signals occur. Modify the circuit to work by using a pulse generator.

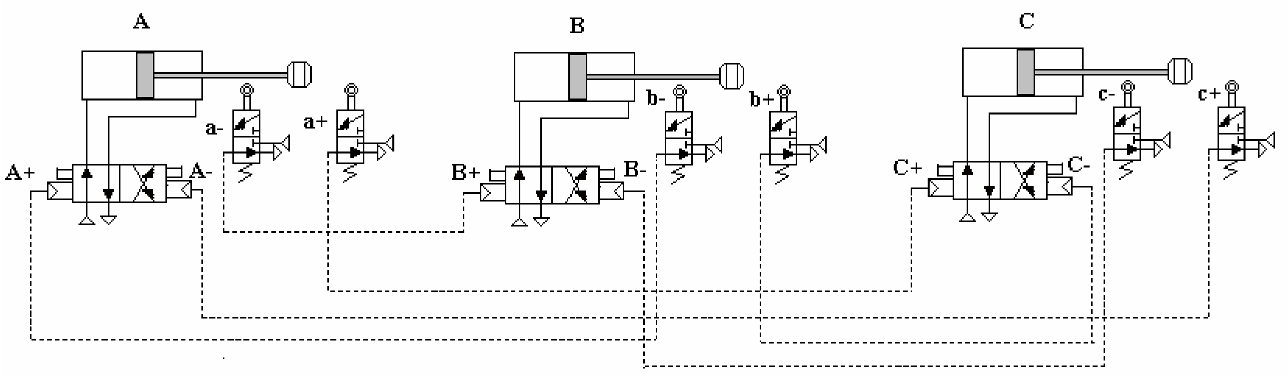


Figure 5

SOLUTION

Suppose that they are all in the retracted position at the start when air is supplied. The air pressures applied to the directional valves are shown in the start position. Valve A will switch because it is the only one with an on and off applied to it so DCV A will switch and the next action will be cylinder A going plus. Air will be sent to C+ and lost from B+ so these changes are shown. The only valve with an on and off signal applied to it is valve C so this will switch to C+. Continue in this way and build up a table as shown, ignoring opposing signals at this stage. The red indicates the change triggered for the next part of the sequence. Build up the table to complete a cycle.

COMMANDS

	START	A+	C+	A-	B+	C-	B-	A+
A+	on	on	on	on	off	off	on	on
A-	off	off	on	on	on	off	off	off
B+	on	off	off	on	on	on	on	off
B-	on	on	off	off	off	on	on	on
C+	off	on	on	off	off	off	off	on
C-	off	off	off	off	on	on	off	off

Examining the table we find that we have opposing signals when C extends and tries to switch off cylinder A (A-). We also have opposing signals when C retracts and tries to switch off cylinder B (B-). These are indicated in blue. We need a pulse generator on the A+ and B+ lines so that they become off after a short time. The working circuit is shown next.

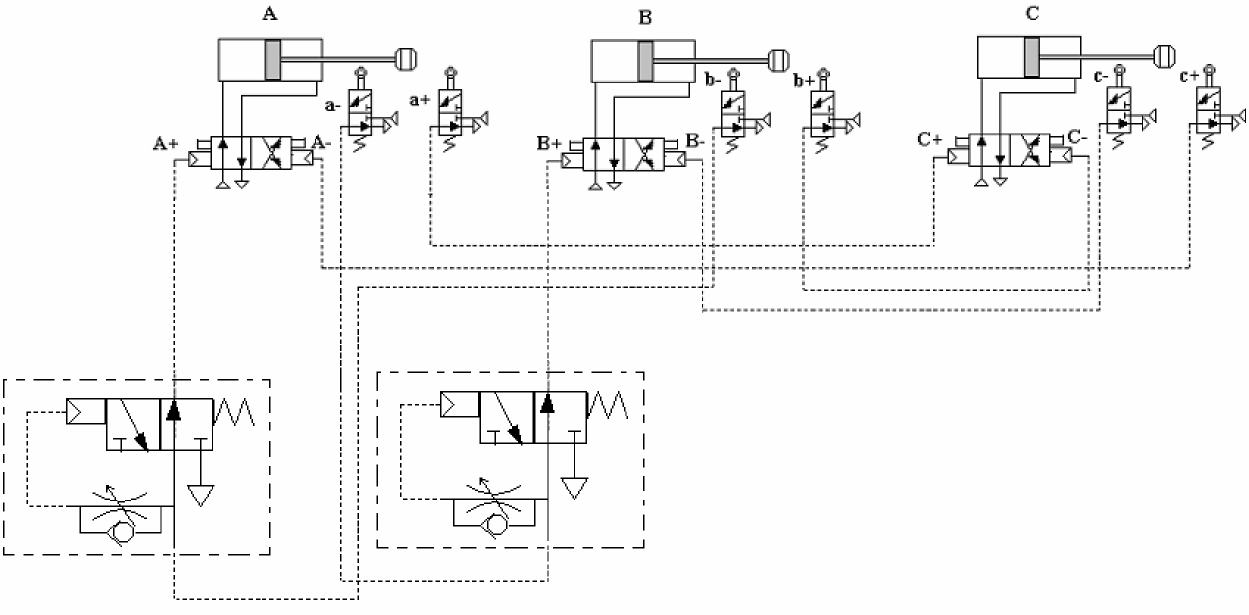


Figure 6

When a sequence requires one or more cylinders to move twice within a cycle, the solution becomes more complicated and a systematic method is needed to produce it. Consider the cycle A+ C+ B+ B- B+ B- C-A-

Cylinders B make two complete motions but cylinders A and C only makes one. Electro-pneumatic systems could overcome this with a programmable logic controller (PLC) but to do the job completely with pneumatics or hydraulics requires a more complex circuit using logic valves. One systematic way to produce such a circuit is called ***CASCADE*** control.

2. CASCADE CONTROL

The following is a brief description of the principles. A full study of this topic would take a disproportionate amount of time for a single module. The principles are similar to those used to programme logic controllers (PLC). Consider the following problem. Two cylinders A and B must perform the following sequence.

A+ B+ B- B+ A- B-

If you tried solving this with direct operation you would end up with opposing feedback signals. The cascade system uses two banks of directional valves. One bank operates the actuators and the other acts as a memory bank. This bank is called the group valves and there purpose is to provide pressure to group lines which are either on or off and hence provides the memory function.

Consider how the feed back signals are obtained for each cylinder.

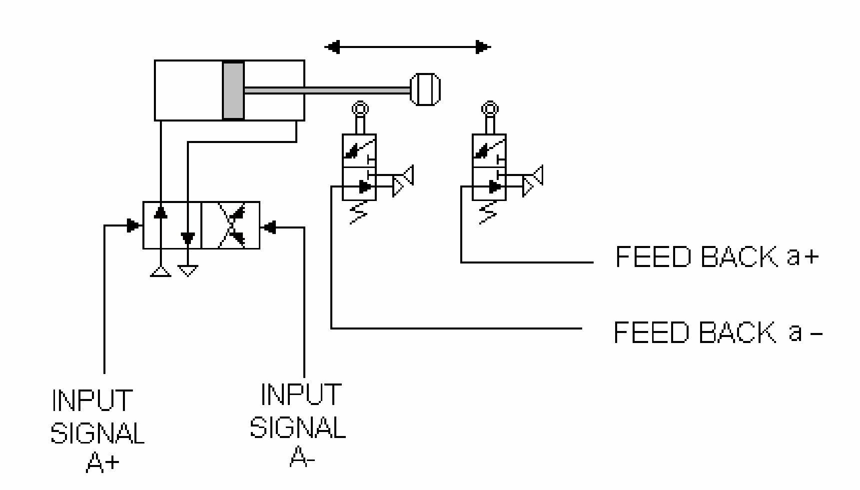


Figure 7

In order to tell the difference between input signals and feed back signals we will use capital letters for the inputs and lower case letters for the feed back.

Each cylinder is controlled by a 4/2 pilot/pilot valve. 5/2 valves are more common for pneumatics and do the same thing. The feed back signals are derived from 3/2 NC roller/spring valves.

It is worth noting that the control valves could be pilot/spring in which event the A- signal is automatic when the A+ signal is removed. This has advantages and disadvantages and deciding which to use is a matter of experience in circuit design.

2.1 CYCLE DIAGRAM

The cycle diagram is a useful tool and shows the status of the cylinders, the input signals and the feed back signals at each point in the cycle. The time intervals are shown as equal but although this may not be the real case, it is irrelevant. It takes one interval for the cylinder to move. Following the application of the input signal, the corresponding feed back signal occurs one interval later.

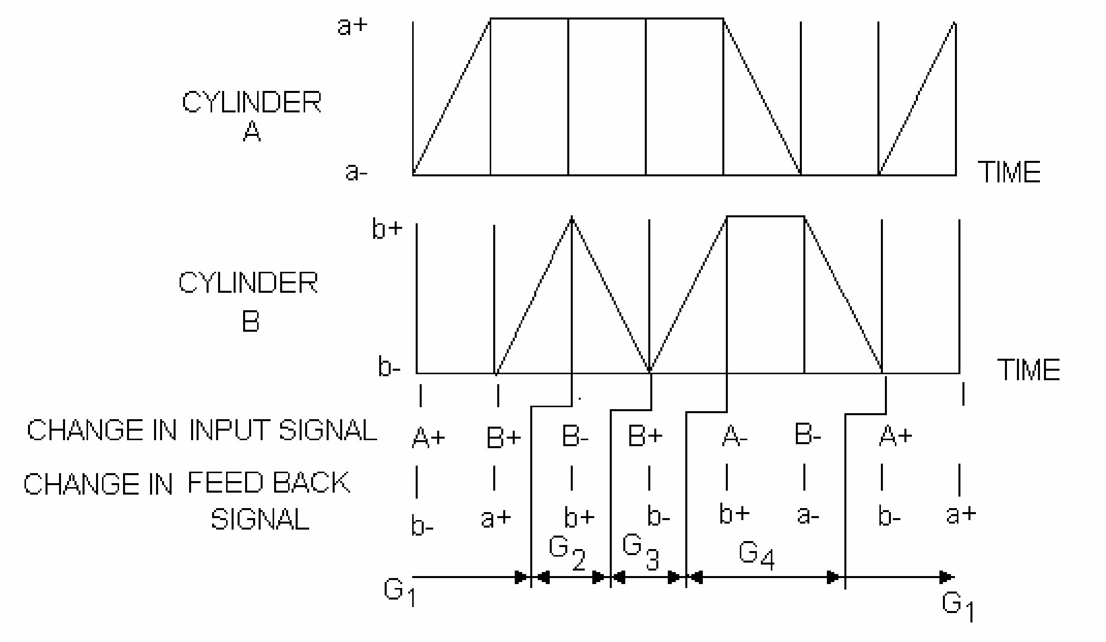


Figure 8

Only show the changes to the input and feed back signals. Divide the cycle into groups. No group must contain the same change twice. If it does, then opposing signals will occur.

If there is more than one way to arrange the groups then the one with the least number of groups should be used. The cycle being studied, surprisingly yields four groups.

Now let’s see how to make these groups into real hardware. Remember the advantage of a PLC is that you don’t need any real hardware but in a pneumatic system you do.

2.2 GROUP VALVES AND LINES

A group is switched on when the group line contains pressure. This requires a 3/2 pilot/pilot valve for each group line. The group is switched off by a reset signal and this comes from the next group line. Every time a group is switched on, it automatically resets and switches off the previous group.

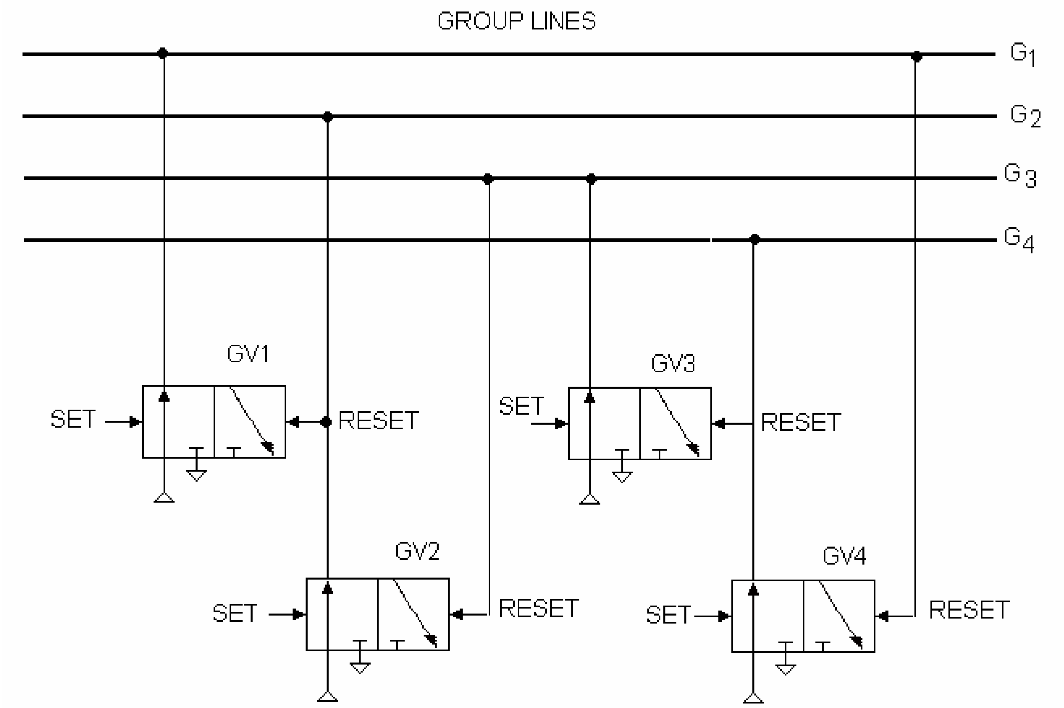


Figure 9

When the set signal is applied to the group valves, it switches on the valve and corresponding group. Now we must consider how to generate the set signals and the command signals. This is helped by writing down the logic statements.

2.3 LOGIC STATEMENTS

We must write out logic statements for switching on and off the input signals. You should use Boolean symbols.

A . B means A and B

A + C means A or C.

Examining input A we see that A+ occurs at the start of group 1 so we write $A+ = G_1$

A is switched off at the start of group 4 so we write $A- = G_4$

B is switched on twice in the cycle so we need an OR

First it is switched on in group 1 but not until feed back a+ occurs. It is also switched on at the start of group 3. The command is as follows.

$$B+ = (G_1 \cdot a+) + G_3$$

B is switched off by the start of group 2 and in group 4 when the feed back a- occurs.

We write $B- = G_2 + (G_4 \cdot a-)$

If we were doing a PLC ladder logic diagram, these would be the logic statements for each rung.

The groups (also known as flags) need a logic statement well. Each group will be automatically cancelled by the next group so we only need to write a command to switch them on. Each group is switched on by the last thing to change in the previous group.

Group 1 is turned on by b- occurring in group 4 so we write $G_1 = G_4 \cdot b-$
Group 2 is switched on by b+ occurring in group 1. $G_2 = G_1 \cdot b+$
Group 3 is switched on by b- occurring in group 2. $G_3 = G_2 \cdot b-$
Group 4 is switched on by b+ occurring in group 3. $G_4 = G_3 \cdot b+$

Note how each group is switched on by the previous group and an event.

2.4 LOGIC CIRCUITS

There are many logic valves in pneumatics but for this exercise we only need OR (shuttle valves) and AND.

Consider how to generate the signal for B+ The command is $B+ = (G_1 . a+) + G_3$
We need an AND valve and an OR valve.

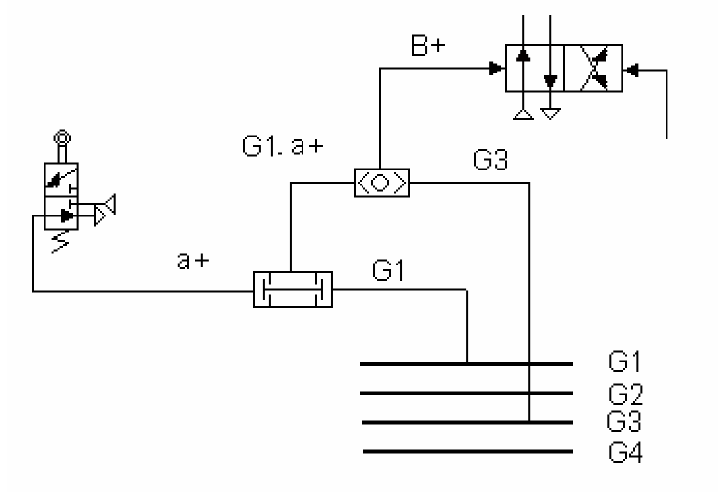
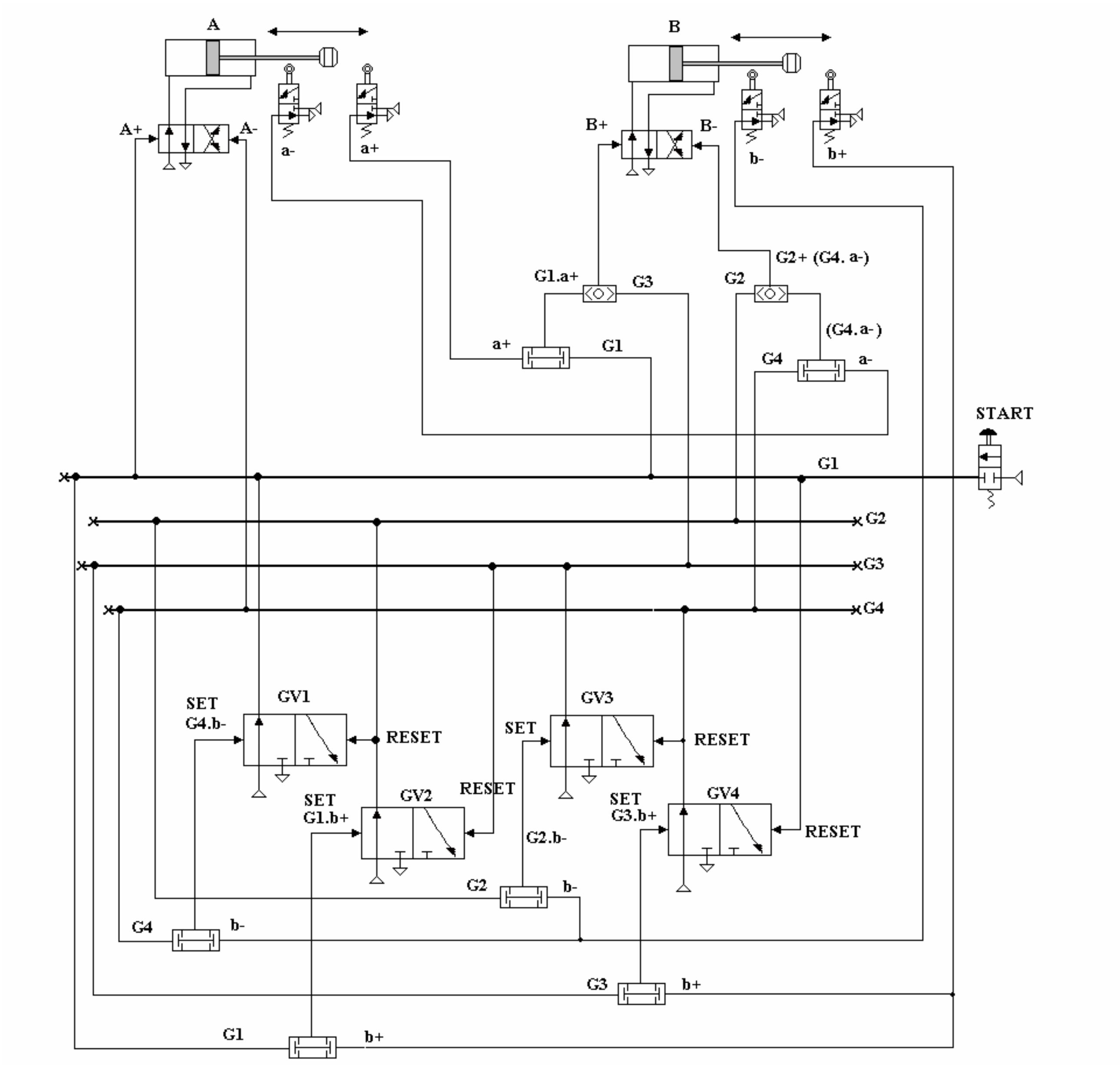


Figure 10

Try writing out individual circuit for all the other commands. The complete circuit is attached.

Note that an additional problem occurs when starting up the sequence. In order to make the sequence start at the correct point a simple start valve pulses pressure into G1 triggers A+.



A
B
A+
A-
a-
a+
B+
B-
b-
b+
G2+ (G4. a-)
G1.a+
G3
G2
(G4.a-)
a+
G1
G4
a-
START
G1
G2
G3
G4
SET
G4.b-
GV1
RESET
SET
GV3
RESET
SET
G1.b+
GV2
RESET
SET
G3.b+
GV4
RESET
G2.b-
G2
b-
G4
b-
G3
b+
G1
b+

Figure 11

SELF ASSESSMENT EXERCISE No.2

A hydraulic machine has two actuators A and B and they must perform the following sequence.

A+B+A-A+B-A-

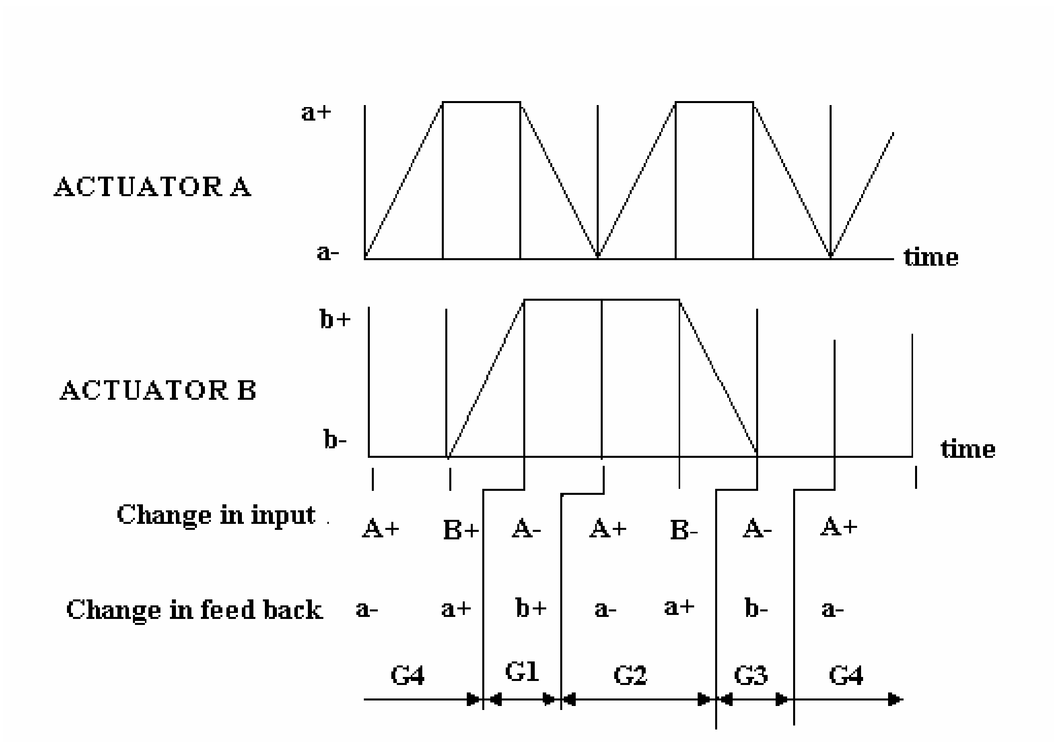
Produce a complete cycle diagram showing how all the groups are arranged.

Write out the logic statements for each command.

Draw the circuit for the complete solution.

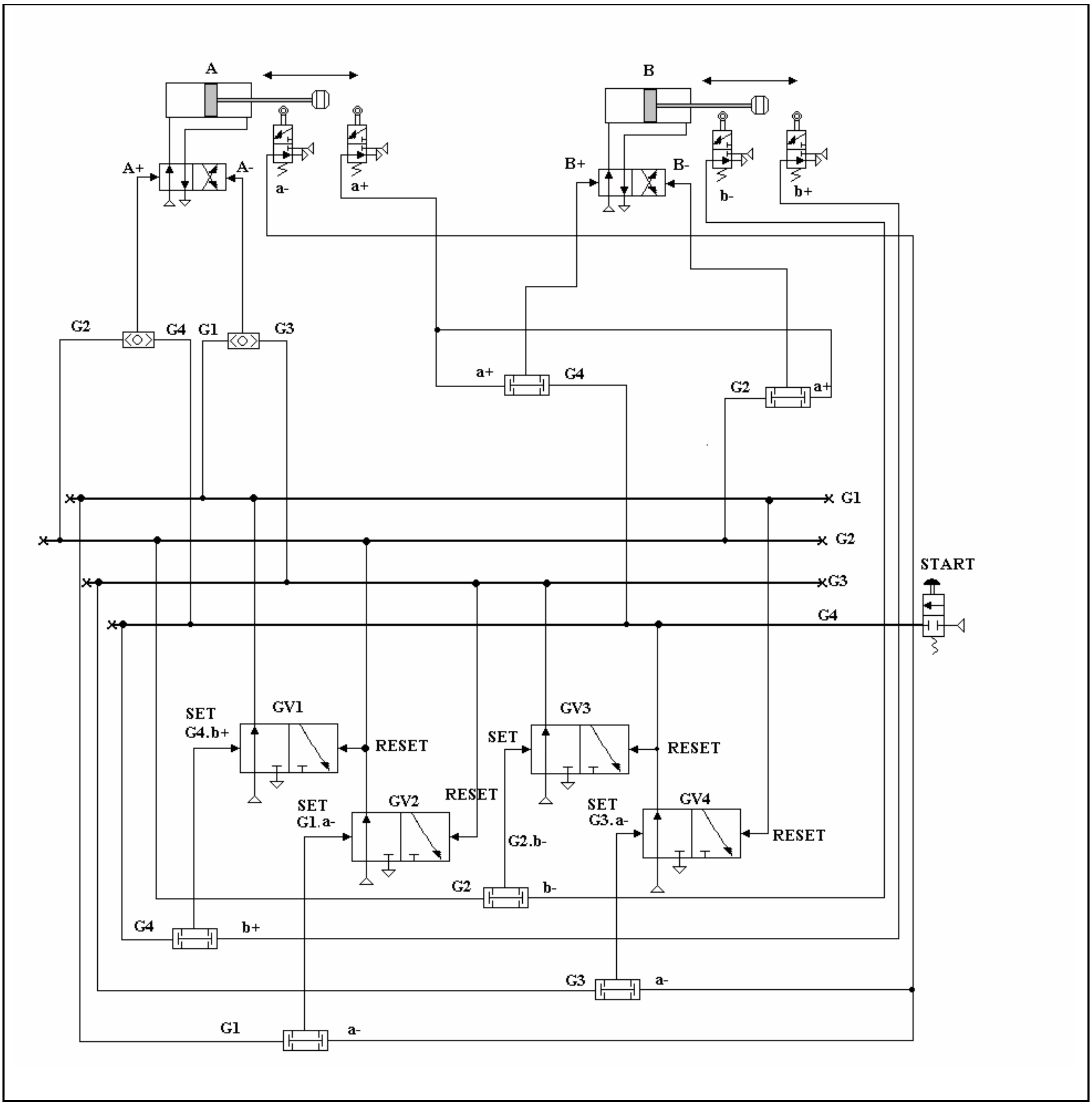
Include start and stop arrangements to ensure that the sequence starts and stops at the correct point regardless of where it is interrupted by the stop signal.

SOLUTION



G1 = G4.b+ G2 = G1.a- G3 = G2.b- G4 = G3.a-

A+ = G4 + G2 A- = G1 + G3 B+ = G4.a+ B- = G2.a+


A
B
A+
A-
a-
a+
B+
B-
b-
b+
G2
G4
G1
G3
a+
G4
G2
a+
G1
G2
G3
G4
START
SET
G4.b+
GV1
RESET
SET
GV3
RESET
SET
G1.a-
GV2
RESET
G2.b-
SET
G3.a-
GV4
RESET
G2
b-
G4
b+
G3
a-
G1
a-