A FLUIDIC POINT-TO-POINT NUMERICAL CONTROL SYSTEM

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ABSTRACT

Fluidics can eliminate many fluid/nonfluid interfaces and perform operations like sensing, power actuation and sequencing, hitherto done by electronic components. Fluidic components contain no moving parts; hence have reduced wear and maintenance problems. They operate satisfactorily in adverse environmental conditions of vibration, temperature, etc.

This paper reports the development of a fluidic numerical control positioning system using mainly fluidic NOR gates. The different fluidic schemes for encoder, decoder, counter and display are described in detail.

Keywords: Fluidics, Numerical Control, Machine Tool.

1. INTRODUCTION

Fluidic technology [1] promises to extend the regime of fluid power into areas long held by electronics and electro-mechanical devices. Fluidic components can perform the work of electronic components in places where it is not feasible to use electronic components due to technical and economical reasons. Fluidic systems offer higher reliability, lower cost, greater environmental tolerance than conventional systems in many applications. This is due to the fact that fluidic systems are simple, eliminate difficult transductions, have few if any moving parts and are more compatible with the process. The low speed of fluidic systems may appear to be a significant limitation, but not as critical a problem in actual application in many cases. Many operations are man paced and speeds of one hundred cycles per second are more than adequate, although some fluidic systems are capable of speeds in excess of 1000 cps. Fluidic technology has such

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promising potential that large number of industries are involved in some phase or other of it. Fluidic devices find application [2] in fields like medical, aerospace, marine, automotive, machine tools, etc.

A fluid system is one in which sensing, control, information processing are performed primarily through utilising fluid-dynamic phenomenon, like coanda (wall attachment) effect, momentum exchange, vortex flow and so on.

2. BASIC CONTROL SYSTEM OF A MACHINE TOOL

A control system for a machine tool must regulate one or more of the following functions : power drive, depth of cut, speed and feed, sequencing of operations, positional control, tool selection and such auxiliary functions as lubrication, supply of coolant and chip removal.

For example, in a closed loop (feedback) system such as that approximated by complex numerical control [3] equipment, the following parameters might be sensed : position, direction, time, sequence, fluid flow rate, pressure, temperature and so on. A typical transfer machine sequence might proceed as follows : clamp work, move work piece to tools, supply coolant, remove chips, retract tool and move to next station.

The basic control functions performed could be generalised to include AND, OR, NOR, timing and memory functions. For general purpose equipment some or all of these functions are performed either manually or by a closed loop feedback system which continually compares actual performance over a broad range with a set of programmed inputs. Actuation can be mechanical, electrical, pneumatic or any combination of these.

3. FLUIDICS FOR MACHINE TOOL CONTROL [4]

The machine tool market appears to hold significant potential for the development and application of fluidic systems and components for the following reasons.

First, many machine tool performance requirements - especially the need for reliability and repeatability and the relative unimportance of speed of response - correspond to fluidic capabilities. Second, because of the widespread use of pneumatic and hydraulics for both power and control functions, fluidic elements could be incorporated into present systems without major design modifications. Fluidics infact could simplify existing systems

by eliminating many of the present fluid/nonfluid interfaces. Third, the industry - including a large number of relatively small, specialised engineering oriented companies would be highly receptive to new ideas.

For the above reasons, the emphasis on fluidics for machine tool control is growing rapidly.

4. FLUIDIC NUMERICAL CONTROL COMPONENTS [5, 6]

For position control of machine tool tables, the system consists of :

A tape reader/selector switches - to give input information, an encoder for giving feedback information, a summing junction, a digital to analog converter, for changing the digital input information to its analog equivalent for amplification and application to direct the motor to move the machine tool table to the desired position. A seven segment display unit indicates the instantaneous position of the table.

Fluidic decade counter is required to store in a fluid logic network, the aggregate number of fluid pulses entered. Decade counters are cascaded binary counters with proper resets.

5. POINT-TO-POINT SYSTEM DEVELOPMENT

The block diagram of a 4 digit (H, T, U, F) manual input, fluidic incremental positioning system 1 is shown in Fig.1. 1.
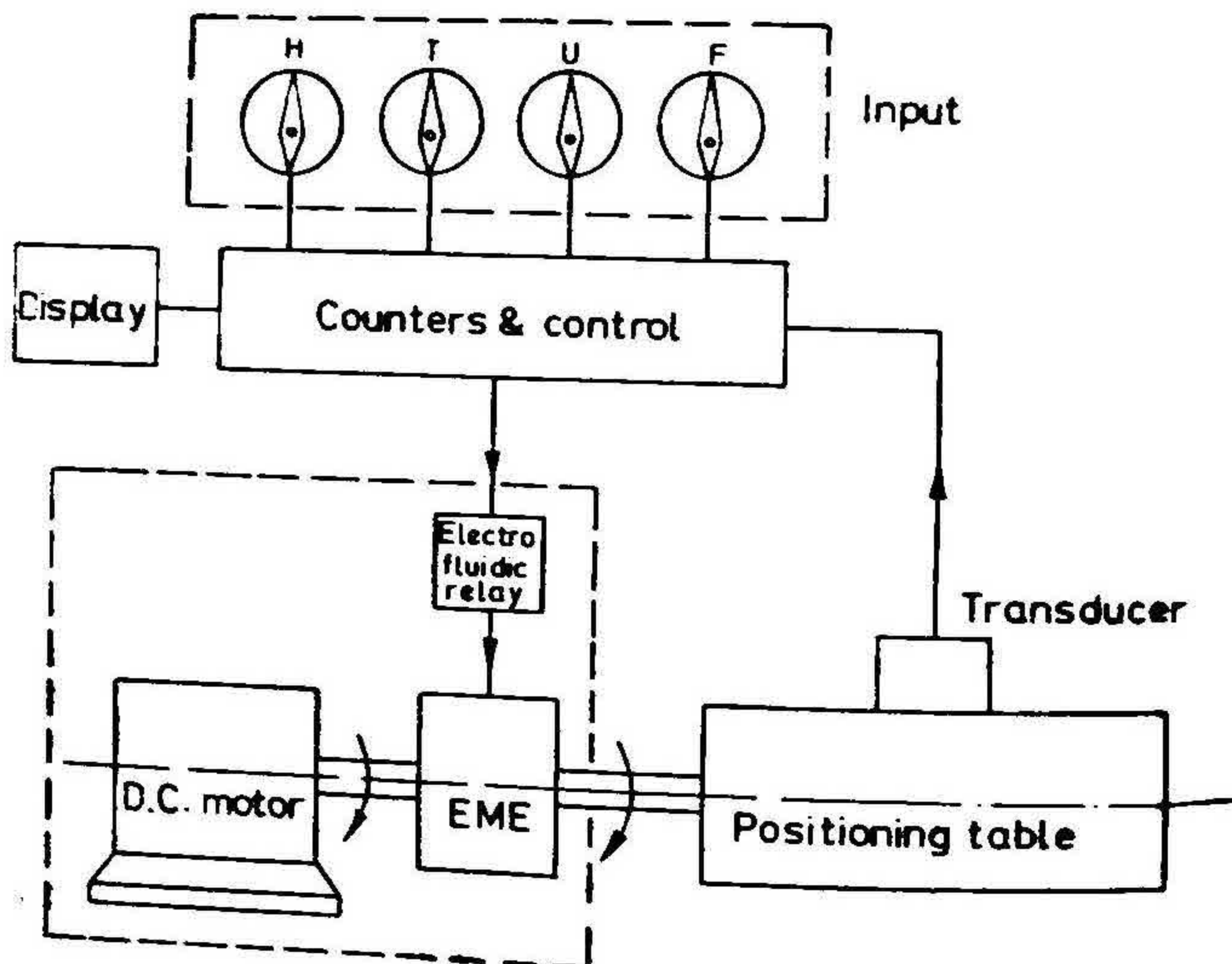

FIG. 1.1. Block schematic of fluidic N/C system.

It contains

1. Selector switches (10 positions), 2. Encoder, 3. Decade (up or down) counters, 4. Decoder, 5. Incremental encoder (Transducer), 6. 7 segment display, 7. control unit, 8. Drive unit, etc.

Details of design and utility of the individual parts are furnished below.

(a) Selector Switch - Fig. 1.2 (a)

The selector switch is the input unit, which permits setting the desired distance through which the work table should move. The 10 positions (0 to 9) of the selector switch predetermine the fluidic down counter states.

(b) Incremental encoder [7, 8] - Fig. 1.2 (b)

Fluidic incremental encoder is a digitiser disc, *i.e.*, a slotted disc to interrupt the flow between the supply nozzle and receiver nozzel. Fluidic jet sensors can be used to sense the presence or absence of the teeth. If the teeth comes in between these nozzles, supply will not reach receiver. Thus for continuous rotation of the disc, pulses are generated which can be down/ up counted, using a decade counter. As the machine table moves, the encoder connected to the leadscrew sends the feedback pulses to the counter.

(c) Display

This is a 7 segment unit consisting of air operated piston segments as shown in Fig. 1.2. (c). Different numbers are displayed depending on the combination of actuation the various pistons. For example, if air to all the 7 segments (a to g) is supplied, we get the number 8.

(d) Counters

A binary counter has 2 states (on and off). It can count two pulses if the initial state is known. 'n' number of cascaded binary counters can count 2^n pulses. A decade counter, can be realized using four cascaded binary counters, which is capable of counting 16 ($= 2^4$) pulses, *i.e.* 0 to 5.1 With proper sets and resets this can be modified into decade counter.

Usually for N/C systems, a BCD down/up counter [9] is employed, since we count down the present value in the counter by giving pulses from the incremental encoder (transducer) which gives 'N' number of pulses for each revolution, where 'N' depends on the required resolution of the system. In a down counter using four fluidic binary counters, when the
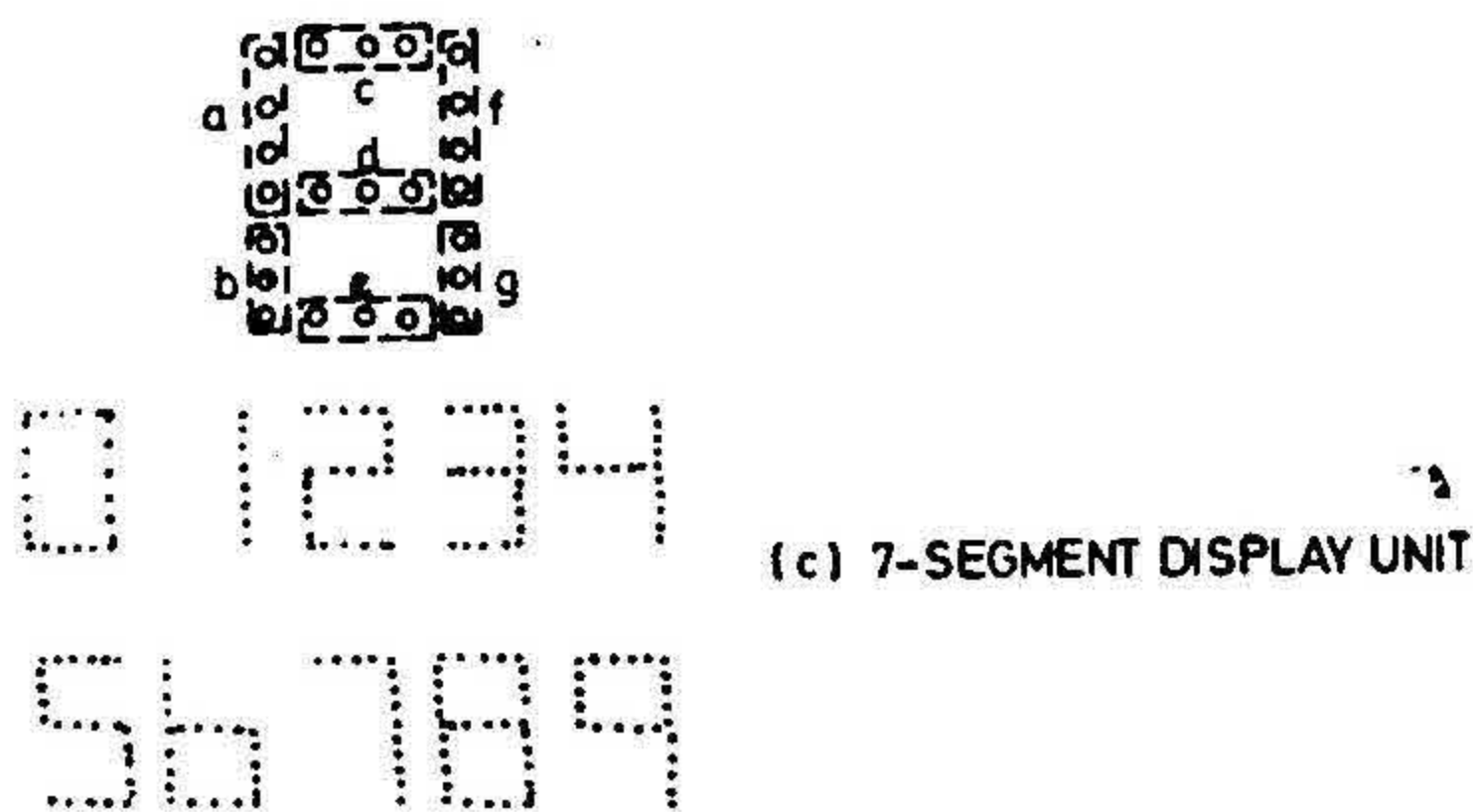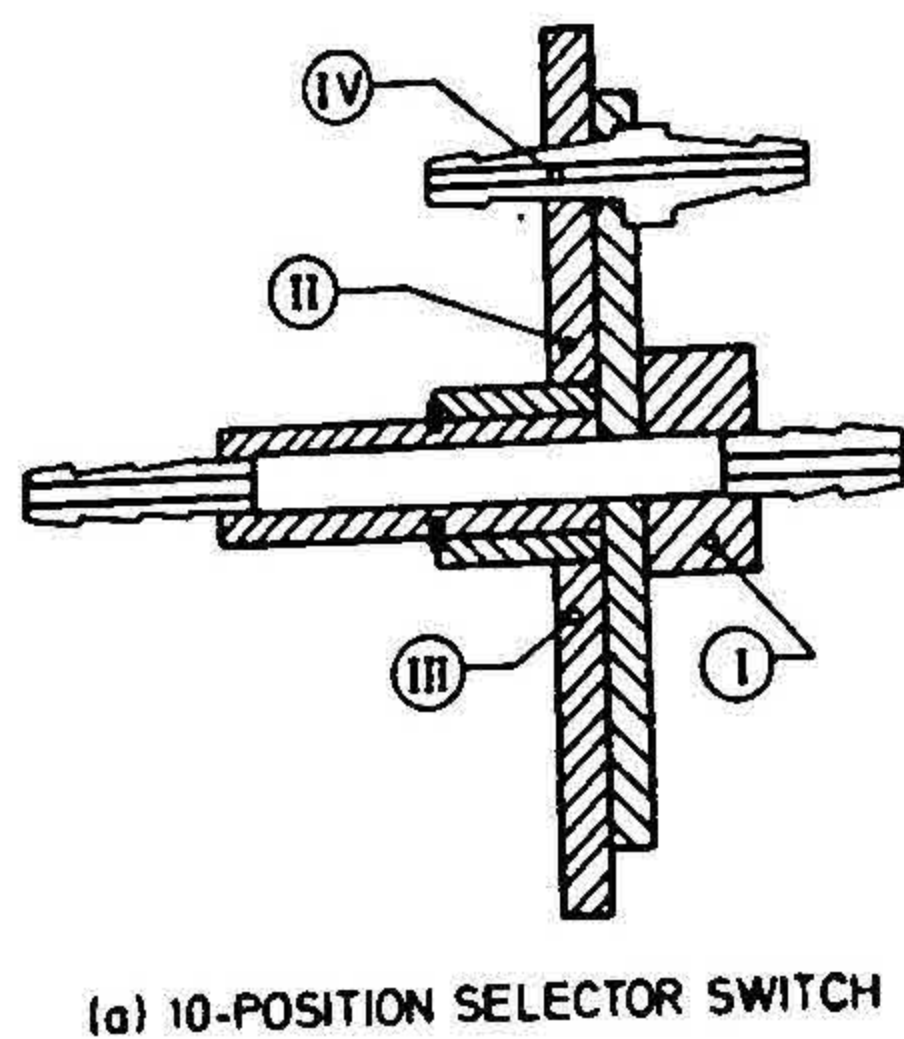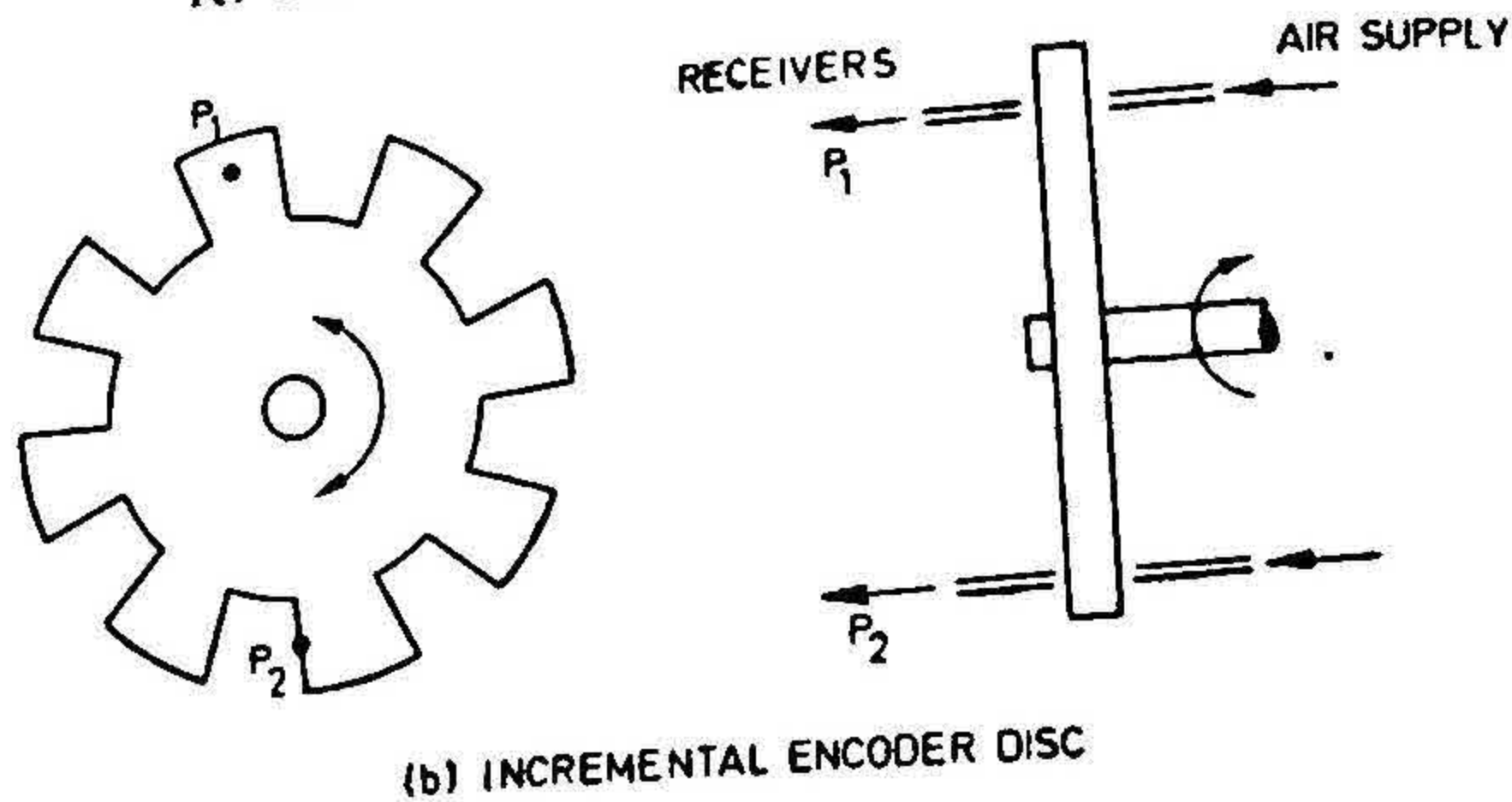
(b) INCREMENTAL ENCODER DISC

(a) 10-POSITION SELECTOR SWITCH

(c) 7-SEGMENT DISPLAY UNIT

Fig. 1.2.

state 0000 (= 0) is reached from the present value, the next state will be 1111 (= 15). For obtaining decade counting action, *i.e.*, to get 1001 (=9) instead of 1111 (= 15), connections from the complimentary output parts

of the binary counters A,B,C, & D are taken as shown in Fig. 1·3, to a 4 input NOR gate. The output of the NOR gate will go high only when the counters read 1111 (= 15). The NOR gate output is used to reset the counters B and C and thus the counter reads as 1111 (=9).

To next stage

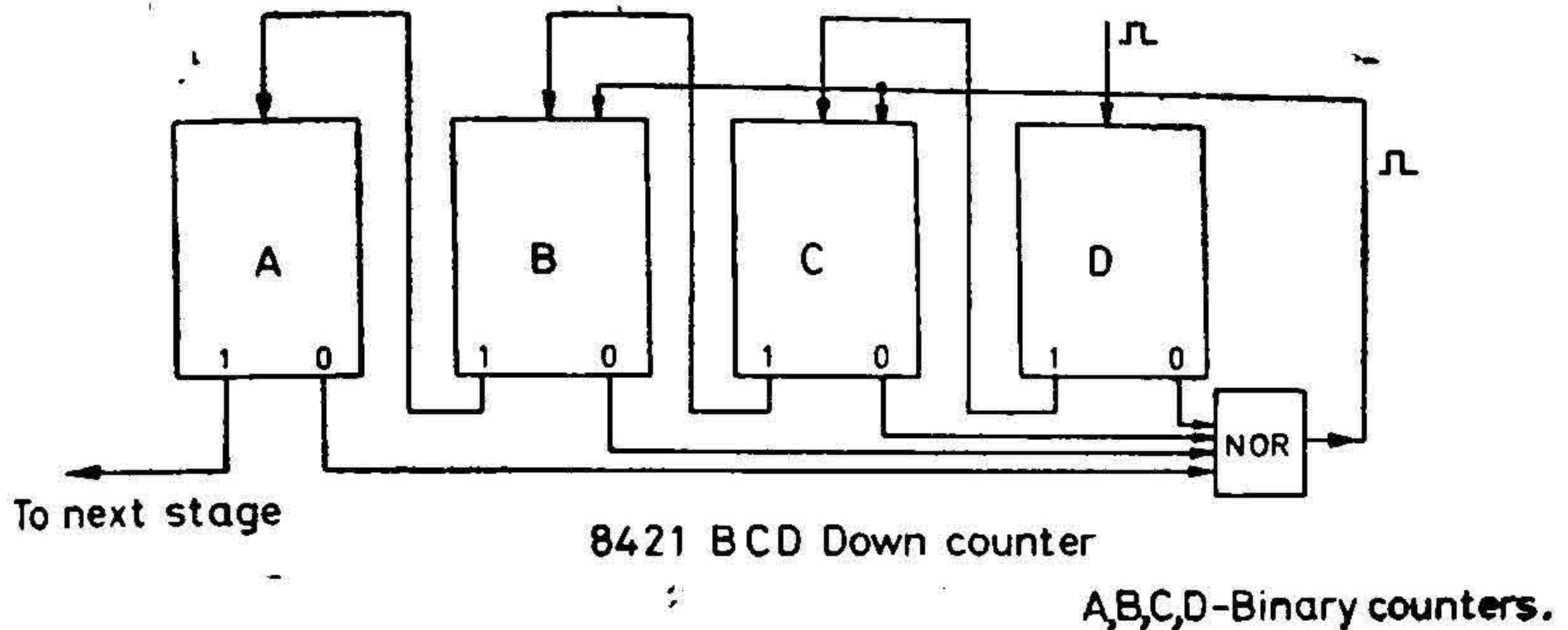8421 BCD Down counter

A,B,C,D-Binary counters.

FIG. 1.3. Fluidic decade counter scheme.

This converts the decimal input to it from the selector switch, into corresponding BCD number to set and reset the binary counter stages. All the ten postioins in the input unit are connected to the NOR gates as shown to get the encoder circuit. The output from the NOR gate is found only if all inputs are simultaneously zero. The circuit makes use of only NOR elements. More than 4 inputs are obtained, by inverting an input twice.

(e) B.C.D. to Decimal Decoder

The counter stores information from the 10 position selector switch and starts down-counting as the pulse is put in. This can be displayed by a 7 segment fluidic piston type display unit. A decoder is necessary for this purpose. A simple decoder is realized using only NOR logic elements.

(f) Decimal to 7 segment decoder : Fig. 1·4.

For display of numbers 0 to 9 in a 7 segment display unit, a circuit using only ' NOR ' logic elements is shown in Fig. 3. A number 4 in the 7 segment display is obtained in this scheme by having outputs from NOR gates D, E, B and A only. Hence singnal to these NOR gates is not supplied from supply 4.
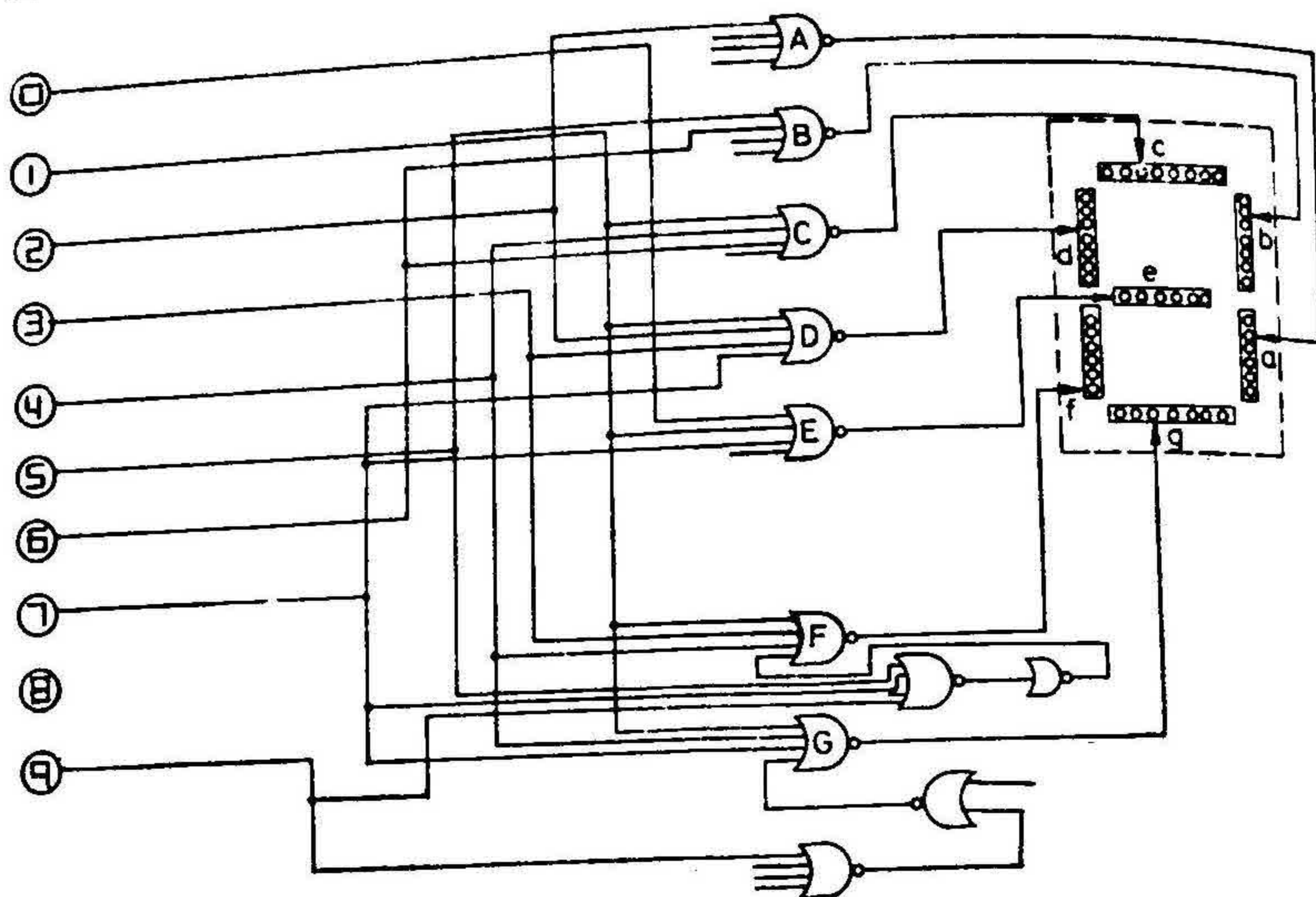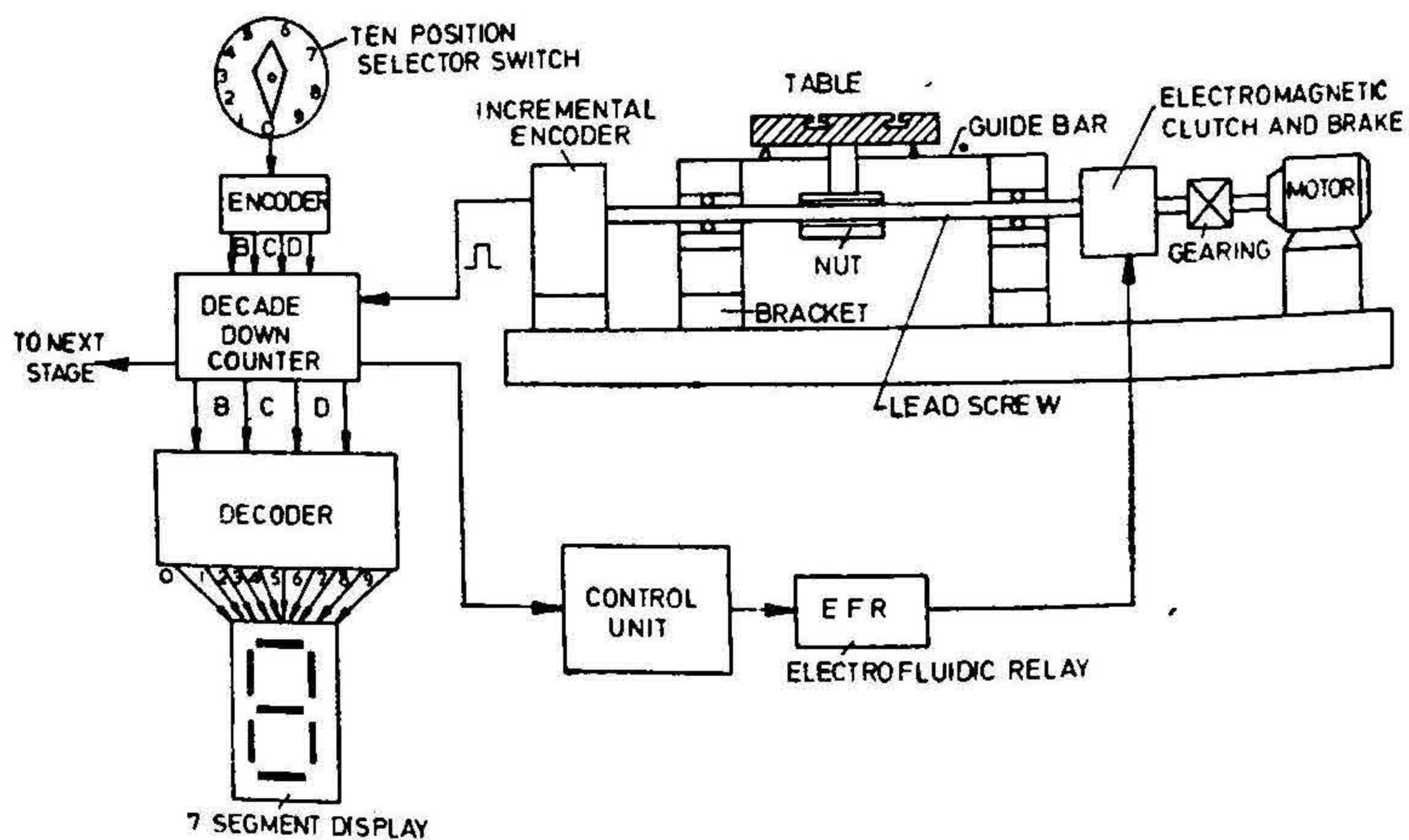
FIG. 1.4. Decimal to 7-Segment Display.

FIG. 1.5. Fluidic single digit incremental positioning system (Block diagram).

6. COMPLETE SYSTEM

The complete block diagram for a single digit incremental positioning is shown in Fig. 1·5. For practical purpose, a control unit with atleast 4 digits is necessary. This can be realised by cascading the decade counter units. The final control signal for controlling the drive unit will come from the 'H' counter.

The various circuits were realized using mainly NOR gates, thus reducing power consumption. The use of integrated flow boards reduces the bulk considerably, in the present scheme. The system can accept about 15 pulses/ second. Pulse shaping may be necessary for higher pulse rates. A pressure ratio of 4:1 should be kept in the counter supply and the decoder flow board, for proper functioning. The pressure in the flow boards should not exceed 4 psi.

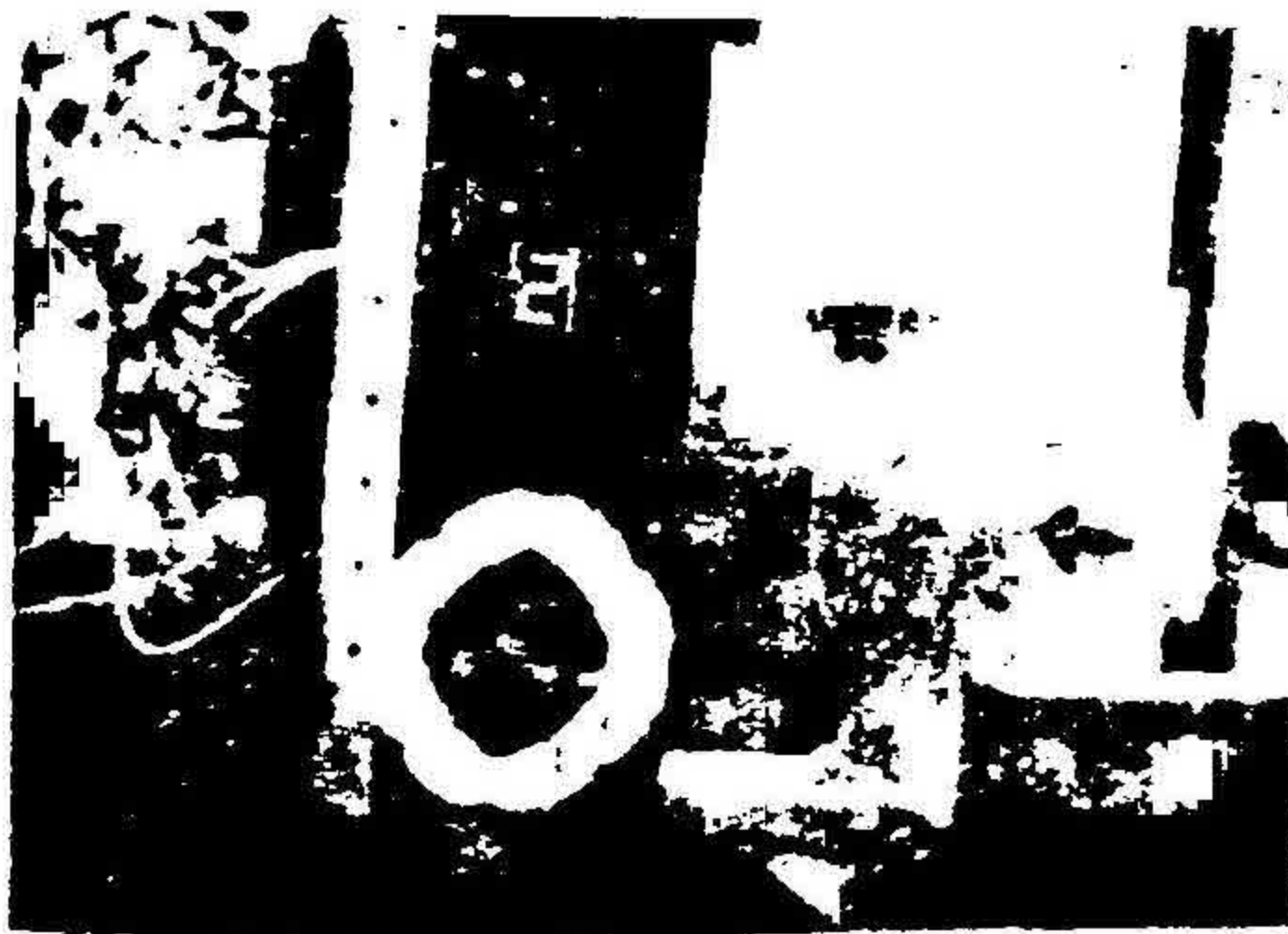The photograph of a fluidic positioning system (one decade) is shown in Fig. 1·6.

FIG. 1·6

7. CONCLUSIONS

Fluidic systems promise increased reliability and generally comparable performance and operating cost. Indirect cost should not be greatly affected by the introduction of fluidic systems. The same programming skills and equipment presumably would be used. The only additional cost would be for additional hardware and perhaps for design changes on the new system. These costs should be considered as part of the investment.

Maintenance and reliability factors, which are more important in satisfactory machine tool operation, favour fluidics. The increased reliability of fluidic systems is due to the elimination of many or all moving parts and high resistance to vibration. The problem arising out of fluid contamination may also be solved by proper filtering and by the enclosing the control system in pressurized chambers.

Nearly one-third of present machine tools, may need a resolution of 0·0025″ only and fluidics can meet these requirements easily. Ultra high precision is beyond present fluidic capabilities, but this will only exclude a small fraction of machine tool applications. Fluidics would be increasingly applied to relatively simple machine tool control functions, for simplifying the existing control system by eliminating inefficient and unreliable fluid/nonfluid interfaces.

Fluidic point-to-point numerical control systems would be able to bridge the gap between the manual/semiautomatic systems and the high cost, sophisticated electronic systems.

ACKNOWLEDGEMENTS

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