

PNEUMATIC COMPUTING TECHNOLOGY OF INTERMITTENT ACTION

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Abstract

Full Text

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*CYBERNETICS
AND CONTROL THEORY*

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PNEUMATIC COMPUTING TECHNOLOGY OF INTERMITTENT ACTION

(Presented by Academician V. A. Trapeznikov, 7 December 1965)

A new method is described for performing computations in pneumatic automation, which makes it possible to carry out, with high accuracy and technical simplicity, basic computational operations on the basis of which a linear remotely controlled pneumatic resistance and other elements are constructed. The set of realizable elements is sufficient for creating pneumatic computing technology based on regular methods of elemental circuit construction, instead of the existing principle of assembling circuits from complex mechanical devices, which leads to redundancy in circuits of a number of units, bulkiness, the need for prolonged design of new devices, and other shortcomings.

The essence of the method set forth consists in using, for computations, the gas equation of state, according to which, for a given gas* and at a certain temperature θ , there exists a single-valued dependence among three gas parameters—absolute pressure** \bar{P} , volume V , and weight G :

$$\bar{P}V = GR, \theta. \quad (1)$$

This equation, valid for real gases over broad ranges of pressure variation, offers the possibility of performing computations with high accuracy for any applied pressure ranges without the use of any converters whatsoever; moreover, its solution can be realized very simply and with high accuracy by means of a pneumatic capacitance, which is an ideal model of the given equation.

The performance of computations can be carried out only intermittently, by alternating operations of computation proper and communication with the supply lines, since the equation of the gas equation of state is valid only for a finite value of the volume, while the computing process requires communication of the solving element with the input and output lines.

Of especially great importance is the presence of four controllable quantities—the three gas parameters and the interruption frequency. This opens broad possibilities for synthesizing elements and circuits of computing technology owing

Fig. 1

Figure 1: Fig. 1

to the variety of available methods, such as: 1) alternating communication of a capacitance with different pressure sources; 2) connection (disconnection) of capacitances; 3) forced introduction of quantities of gas into a capacitance; 4) forced change of the pressure in a closed chamber from one value to another; 5) forced change of the volume of a closed chamber from one fixed value to another.

One of the most important realizable elements is a linear pneumatic resistance with a pulsating flow ⁽¹⁾.

A **pulsating resistance** (Fig. 1) consists of a capacitance 1 and two contacts 2 and 3 connected to it, which connect the capacitance alternately with output lines 4 and 5.

* The gas constant $R_r = \text{const}$.

** Here and below in the article, gauge and absolute pressure are denoted respectively by P_i and \bar{P}_i .

Applying equation (1), it can be shown that, as a result of the arrival of one control pulse P_t at both contacts,* the amount of gas in the capacitance 1 changes by ΔG , i.e., from one output line to the other there passes an amount of gas (a portion) equal to

$$\Delta G = \frac{V}{R_r \theta} (\bar{P}_1 - \bar{P}_2) = \frac{V}{R_r \theta} (P_1 - P_2), \quad (2)$$

where \bar{P}_1 and \bar{P}_2 are the absolute pressures in lines 4 and 5, respectively.

Fig. 1. Diagram of a pulsating resistance

It follows from equation (2) that the reduced resistance forms an intermittent flow rate (in portions) and operates not in real time, but in the “time” of the discrete parameter n —the number of pulses. The conductance $\alpha_i = V/R_r \theta$ is not a function of real time; therefore a pulsating resistance makes it possible to operate in any “time,” i.e., one specified by any variable and proceeding either discretely or, with the required approximation, continuously.

The weight flow rate of gas per unit of real time t is determined with the aid of equation (2):

$$\frac{dG}{dt} = \frac{Vf}{R_r \theta} (P_1 - P_2) = \alpha (P_1 - P_2),$$

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

where f is the frequency of supply of the pulses P_t , which determines the transmission frequency of gas portions; α is the conductance of the pulsating resistance in real time.

The conductance α of the resistance in real time is directly proportional to the frequency f of the contact-control signal P_t and to the magnitude of the capacitance V , which makes it possible to have either a resistance with conductance unregulated during the computation process, or one with linearly controlled conductance.

Fig. 2. Circuit with deep negative feedback in frequency. P_1 , P_2 , and P_0 are input signals; f is the output signal, frequency-modulated

Fig. 3. Diagram of a sweep system. Δ is a repeater with shift; K_1 is a contact intended for introducing the initial level and controlled by the signal P_t

The controllability of the resistance makes it possible to construct circuits with feedback in pressure, frequency, and capacitance, implementing a broad class of linear and nonlinear computational operations both discretely and, with the required approximation, continuously in time, as well as combined electrohydropneumatic circuits with the corresponding execution of the contact drives.

Circuits with deep negative pressure feedback on an amplifier with one variable input, and circuits with positive pressure feedback on an amplifier with a stabilized transfer coefficient (with parametric compensation), do not differ in their structure from analogous electronic circuits intended for perform-

* That is, as a result of one opening of each contact.

...of linear computing operations, but they have certain additional possibilities owing to the controllability of pulsating resistances.

The possibility of controlling the conductance of pulsating resistances, without installing additional converters, by means of a frequency-modulated signal is used for constructing circuits with frequency feedback that perform a number of nonlinear operations on pressures and frequencies, as well as pneumatic-frequency transformations. In this case (Fig. 2) the compensating-feedback channel contains a $P \rightarrow f$ converter of pressure into a frequency-modulated signal.

Circuits with feedback in terms of the capacitance of a pulsating resistance have a structural diagram analogous to circuits with frequency feedback, with

Fig. 4. Diagram of a multi-input converter of pressures into intermittent flow rate.

Figure 4: Fig. 4. Diagram of a multi-input converter of pressures into intermittent flow rate.

the essential difference that, instead of a pressure-to-frequency converter—on whose characteristics no requirements for accuracy and stability are imposed—they require the use of accurate converters of pressures into capacitance, in a number equal to the number of controlled pulsating resistances.

Analog-to-digital and digital-to-analog conversions are carried out on the basis of a scanning system, which is an intermittent integrator with a constant input (Fig. 3). The circuit shown does not require intermediate conversion into a time interval or the use of a stable-frequency generator.

Fig. 4. Diagram of a multi-input converter of pressures into intermittent flow rate. 2, 3 are contacts; 4, 5 are output lines, whose pressures are P_1 and P_2 , respectively; $V_1 \div V_m$ are variable capacitances; O_{i1}, O_{i2} are mechanical travel limiters determining the values V_{i1} and V_{i2} of the capacitances during displacement of the drives $Pr.i$.

Another important device illustrating the possibilities of the proposed method is a **multi-input converter of pressures into intermittent flow rate** (Fig. 4).

The capacitance of the converter consists of m variable capacitances, each taking one of two values V_{i1} and V_{i2} depending on the level of the signal P_i controlling the drives $Pr.i$, and $r - m$ constant capacitances V_i , each of which, depending on the input discrete signal D_i , can be connected or not connected to the converter capacitance by means of contacts K_i . The weighted flow rate per unit time is

$$\frac{dG}{dt} = \frac{f}{R_r \theta} \left[\bar{P}_1 \sum_{i=1}^m D_i V_{i1} - \bar{P}_2 \sum_{i=1}^m D_i V_{i2} + \sum_{i=m+1}^r D_i V_i (\bar{P}_1 - \bar{P}_2) \right].$$

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1. E. V. Fulim, Pulsating linear pneumatic resistance, French patent No. 1,412,669, issued 23 VIII 1965 with priority of 21 X 1964.

Note: Figure translations are in progress. See original paper for figures.

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