DESIGN AND IMPLEMENTATION OF COMPARATOR CIRCUIT MODEL USED AT AUTOMATIC ADJUSTING SYSTEMS WHICH EQUIP SPRINKLING MACHINERY

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Abstract. The most important demand imposed for sprinkling treatments is to ensure the stability of liquid rate. That is the reason for what the sprinklers are fitting out with automatic adjusting systems, in order to automatize the working process. Such system cannot work without an adequate comparator circuit. The paper presents the constructive and functional analysis of a comparator circuit, used for speed and flow signals. In the block scheme of electronic equipment for automatic adjustment of liquid flow with displacement velocity, the comparator circuit is designed to process information presented in the form of input voltages and output generating commands to be applied to the electric motor (that drives the fluid flow control valve). The flow control valve is electrically operated and must be driven in both directions, so that the comparator circuit will generate two separate commands in the form of electrical signals. These electrical signals are amplified by the power amplifier of the equipment, at an adequate level to drive the motor. For designing such a circuit, first it is necessary to establish the proper transfer functions, for command and stationary processes. Based on transfer functions an experimental model of a comparator circuit was carried out. To verify the functionality of the circuit in laboratory conditions two signal generators were used, mounted at the inputs of the speed transducer, respectively liquid flow transducer. Each generator ensures an rectangular signal, with frequencies belonging to the work domain of the transducers. From the data base analysis and the obtained results it has been ascertained that the comparator circuit works in concordance with the specific transfer functions, for those two distinct operating modes (transitive and stationary).

Keywords: sprinkling machinery, adjusting system, electrical signals, comparator circuit, transfer functions.

Introduction

For achieving a comparator circuit (for speed and flow signals) it is necessary to have in view the block scheme of the automatic adjusting system of liquid flow, varying with displacement velocity (Fig. 1).

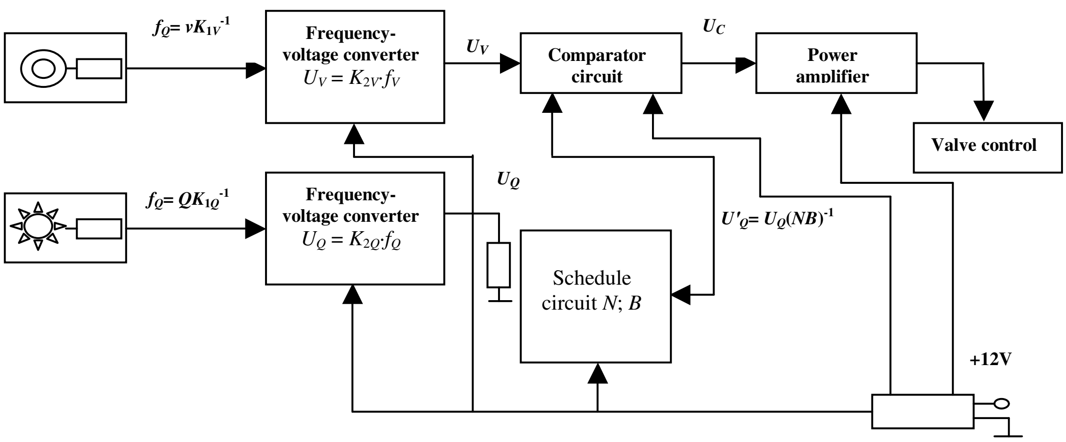

Fig. 1. **Block scheme of the automatic adjusting system of liquid flow, depending on the variation of displacement velocity**

Materials and methods

The transducers for speed and liquid flow are of digital type, having the following transfer functions [2]:

$$V = K_{1V} \cdot f_V, \text{ m} \cdot \text{s}^{-1} \quad (1)$$

$$Q = K_{1Q} \cdot f_Q, \text{ m} \cdot \text{s}^{-1} \quad (2)$$

where f_V – frequency of impulses generated by the speed transducer, s^{-1};
f_Q – frequency of impulses generated by the flow transducer, s^{-1};

K_{1V}, K_{1Q} – proportional coefficients.

These signals are transformed in analogous sizes (voltages, currents):

$$U_V = K_{2V} \cdot f_V, \text{V} \tag{3}$$

$$U_Q = K_{2Q} \cdot f_Q, \text{V} \tag{4}$$

where U_V – continuous voltage generated by the frequency-voltage converter, accordingly to displacement velocity, in volts;
U_Q – continuous voltage generated by the frequency-voltage converter, accordingly to displacement velocity, in volts;
K_{2V}, K_{2Q} – proportional coefficients.

Having in view the calculation relation for the liquid rate and taking into account the relations (1), (3), and (4), result [2]:

$$N = \frac{Q}{B \cdot V} = \frac{K_{1Q} \cdot K_{2V}}{K_{1V} \cdot K_{2Q}} \cdot \frac{U_Q}{U_V \cdot B} \tag{5}$$

If the proportional coefficients are chosen that $\frac{K_{1Q} \cdot K_{2V}}{K_{1V} \cdot K_{2Q}} = 1$, result:

$$U_V = \frac{U_Q}{N \cdot B}, \text{ V.} \tag{6}$$

Making the marking $U'_Q = \frac{U_Q}{N \cdot B}$, relation (6) became:

$$U_V = U'_Q, \text{ V.} \tag{7}$$

The relations (6) and (7) show that for achieving the adjusting function, the electronic block must contain a comparator circuit, which has the role to compare the voltage U_V (accordingly to displacement velocity), with a fraction of U_Q voltage. The divided factor is ($N \cdot B$), where the liquid rate (N) and work wide (B) are imposed sizes [1].

Varying with the result of comparison, the circuit will generate (at output) adequate commands, applied to the electric engine (which sue the valve control). The driving of the valve control must be done in two senses.

For an optimal function of the adjusting system, the comparator circuit must work on the base of the following transfer functions [2]:

1. For the command regime of the control valve (transient process):

$$\left.\begin{array}{l} U_V > U'_Q \rightarrow U_C = U_{C1} \\ U_V < U'_Q \rightarrow U_C = U_{C2} \\ U_V = U'_Q \rightarrow U_C = U_{C0} \end{array}\right\} \quad \Delta U_H = 0$$

2. For the stationary process:

$$|U_V - U'_Q| < \Delta U_H$$

$$U_C = U_{C0} \, \Delta U_H \neq 0$$

where U_{C1} – signal at the output of the comparator circuit, which establishes the increase of liquid flow;
U_{C2} – signal at the output of the comparator circuit, which establishes the decrease of liquid flow;
U_{C0} – null command voltage at the output of the comparator circuit (0 volts);
$|U_V - U'_Q| = \Delta U_H$ – difference between the voltages U_V and U'_Q, for that the comparator circuit does not generate any command ($U_C = 0$).

The work of the comparator circuit in this mode ensures in the frame of transition process (when the equipment achieves an effective correlation of the liquid flow with displacement velocity) maximum sensibility ($\Delta U_H = 0$).

A new command of the valve control will be unleashed when the variations of the voltages U_V and U'_Q exceed on the admissible ($|U_V - U'_Q| < \Delta U_H$).

The experimental model of a comparator circuit is presented in Figure 2. The inputs of the proper comparator circuit (achieved with integrated circuits IC_3 and IC_4) are represented by the inputs of the integrated circuits IC_1 and IC_2, mounted in such way to ensure low impedances at output [2]. The outputs of the comparator circuit are marked with A and B and the states of these outputs can take the following values:

1. in point A:

   $U_{output\ A} = 0$ (stationing state – no command);

   $U_{output\ A} = U_{C1}$ (command for opening the valve control and increase the liquid flow);

2. in point B:

   $U_{output\ B} = 0$ (stationing state – no command);

   $U_{output\ B} = U_{C1}$ (command for opening the valve control and decrease the liquid flow).

For achieving and applying voltage ΔU_H (accordingly with the transfer functions) a constant current generator was used, made up by the transistor T_1, resistors R_2, R_3, R_4, diode Z_1 and capacitor C_1. The collector current (I_C) of the transistor T_1 establishes the voltage $\Delta U_H = I_C \cdot R_1$.

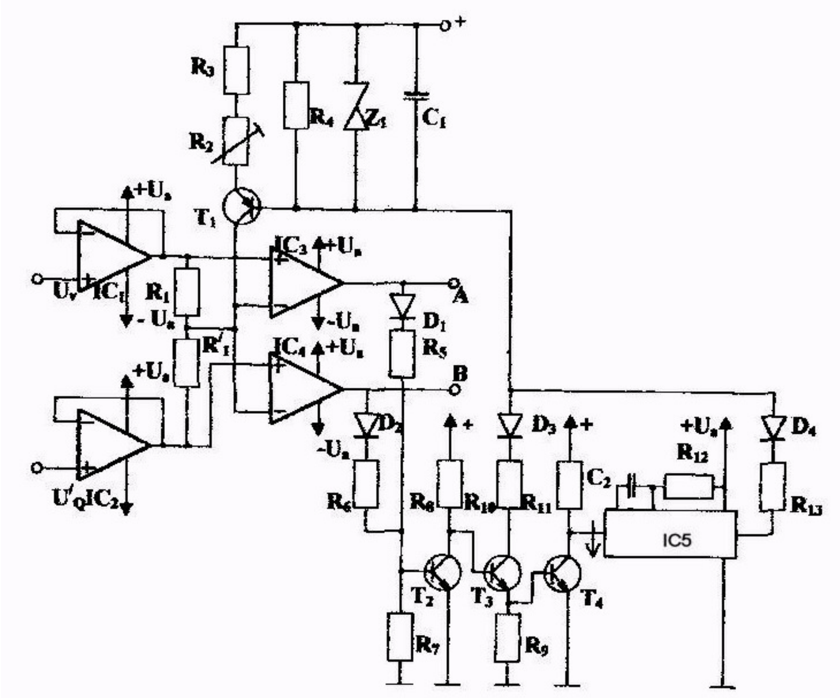

Fig. 2. **Electronic scheme of comparator circuit**

The voltages of the outputs A and B are assumed with a circuit achieved with the diodes D_1, D_2 and resistors R_5, R_6. These voltages are applied on a command circuit (of the constant current generator), achieved with the transistors T_2, T_3, resistors $R_7 \div R_{10}$ and diode D_3. It can be observed that in stationary state (when on the outputs A and B, voltages are null), the transistor T_2 is locked, transistor T_3 is open and the constant current generator is active (voltage ΔU_H is present).

In the transition process (when at the outputs A and B there are present voltages U_{C1}, respectively U_{C2}) the transistor T_2 is open (T_3 transistor is locked and $\Delta U_H = 0$). This situation is available until the disappearance of the command voltage at the outputs A, or B ($U_V = U'_Q$). In this moment the constant current generator is activated (through the transistor T_4) and the voltage ΔU_H is maintained on time interval for eliminating the appearance of some oscillations in the functioning of the circuit. The diagram of voltages in different points of the scheme is presented in Figure 3.

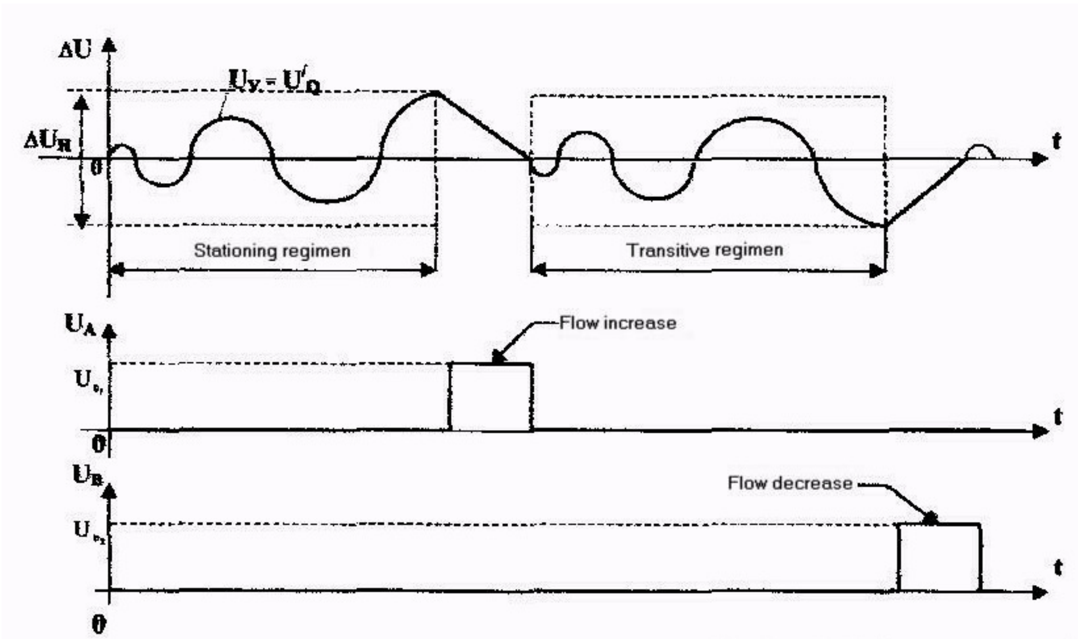

Fig. 3. **Diagram of voltages in different points of the scheme**

It can be observed that in the stationary state, the voltage ΔU_H is present and if $|U_V - U'_Q| < \Delta U_H$, U_{C1} and U_{C2} are nulls (comparator circuit does not give any command). If $|U_V - U'_Q| > \Delta U_H$ (the comparator circuit has a maximum sensibility), at the outputs of the comparator there are the voltages U_{C1} or U_{C2} present, which command the increase (or decrease) of the liquid flow until the scheduled value. In this moment, the voltage ΔU_H is generated again and the comparator circuit enters into a stationary state (until a new correction of liquid flow is necessary).

Results and discussion

The comparator circuit ensures a hysteresis zone around the value of the voltages which are compared. On this zone, the circuit does not give any command, for eliminating the phenomenon of super-adjusting. The hysteresis voltage was settled at the value of 10 mV (with aid of a half-adjustable potentiometer R_2). In order to check the functioning of the comparator circuit the test stand as in Figure 4 has been achieved.

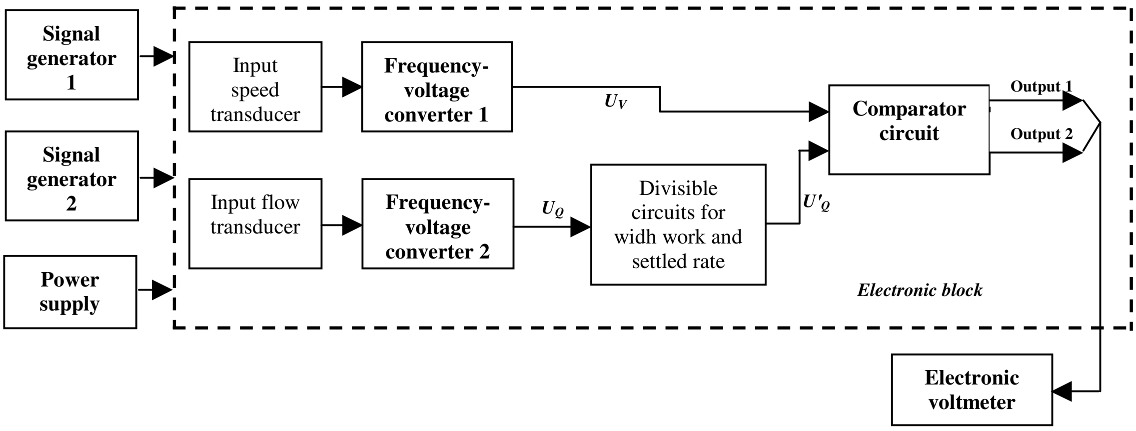

Fig. 4. **Test stand for checking the comparator circuit**

There were two signal generators used (mounted at the inputs of the speed transducer, respectively liquid flow transducer). Each generator ensures a rectangular signal with the amplitude approximately of 300 mV and frequencies belonging of work domain of the transducers. With the aid of an electronic voltmeter the states of those two outputs of the comparator circuit can be observed (function of difference between the input voltages U_V and U'_Q).

The tests were achieved for three values of voltage ($U_V = 700$ mV, $U_V = 4000$ mV, $U_V = 8000$ mV), belonging of the work domain of the frequency-voltage converters.

At each determination it was started at the equality $U_V = U'_Q$. After increasing the frequency applied on the input of the liquid flow transducer the increase of U'_Q. was obtained It has been ascertained that $U'_Q = U_V + 5$ mV, the output 1 passed in state UP (9V), output 2 staying in state DOWN (0V).

If the generation of the frequency is achieved in opus sense, the output 1 come back in state DOWN (0V), at $U_V = U'_Q$.

In the case in which the decrease of voltage U'_Q until the value $U'_Q = U_V – 5$ mV is continued, the output 2 passed in state UP (9V), output staying in state DOWN (0V). Output 2 passed in state DOWN, if the scavenging of the frequency is invert (when $U_V = U'_Q$). The results of these determinations are presented in Table 1.

Table 1

Values of voltages at the outputs of the comparator circuit

U_V = 700 mV			U_V = 4000 mV			U_V = 8000 mV		
U'_Q	$U_{output\ 1}$,V	$U_{output\ 2}$,V	U'_Q	$U_{output\ 1}$,V	$U_{output\ 2}$,V	U'_Q	$U_{output\ 1}$,V	$U_{output\ 2}$,V
700	0	0	4000	0	0	8001	0	0
701	0	0	4001	0	0	8002	0	0
702	0	0	4002	0	0	8003	0	0
703	0	0	4003	0	0	8004	0	0
704	0	0	4004	0	0	8005	9	0
705	9	0	4005	9	0	8006	9	0
706	9	0	4006	9	0	8004	9	0
705	9	0	4005	9	0	8000	0	0
702	9	0	4002	9	0	7999	0	0
700	0	0	4000	0	0	7998	0	0
699	0	0	3999	0	0	7997	0	0
698	0	0	3998	0	0	7996	0	0
697	0	0	3997	0	0	7995	0	9
696	0	9	3996	0	0	7996	0	9
695	0	9	3995	0	9	7997	0	9
696	0	9	3996	0	9	7998	0	9
694	0	9	3998	0	9	7999	0	9
692	0	9	3999	0	0	8000	0	0
691	0	9	4000	0	0	–	–	–
700	0	0	–	–	–	–	–	–

Conclusions

1. From the data base analysis and the obtained results it has been ascertained that the comparator circuit works in concordance with the specific transfer functions, for those two distinct processes (transitive and stationing);
2. Ensuring a hysteresis zone, the comparator circuit eliminates the super-adjusting phenomenon and the risk to unleash oscillations of the work regime (which can have useless requirement for the valve control).

References

1. Alexandru T., Glodeanu M., Exploitation of agricultural machines. Sitech Publishing House, Craiova, 2009, pp. 118 – 122.
2. Glodeanu M., Theoretical and experimental researches concerning the automatic correlation of liquid flow with displacement velocity at sprinkling machines. PhD Thesis, Transilvania, University of Brasov, 2000, pp. 121 – 123.