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Verification of operation of the actuator control system using the integration the B&R Automation Studio software with a virtual model of the actuator system

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Abstract. In the work is analysed a sequential control system of a machine for separating and grouping work pieces for processing. Whereas, the area of the considered problem is related with verification of operation of an actuator system of an electro-pneumatic control system equipped with a PLC controller. Wherein to verification is subjected the way of operation of actuators in view of logic relationships assumed in the control system. The actuators of the considered control system were three drives of linear motion (pneumatic cylinders). And the logical structure of the system of operation of the control system is based on the signals flow graph. The tested logical structure of operation of the electro-pneumatic control system was implemented in the Automation Studio software of B&R company. This software is used to create programs for the PLC controllers. Next, in the FluidSIM software was created the model of the actuator system of the control system of a machine. To verify the created program for the PLC controller, simulating the operation of the created model, it was utilized the approach of integration these two programs using the tool for data exchange in the form of the OPC server.

1. Introduction

Verification of operation of the actuating system of the control system at the design stage of the machine allows for early elimination of errors related to its way of functioning. The use of virtual systems to verify the operation of the operating system of the designed machine allows for virtual testing without the need to purchase actuators as well as signal, control and setting elements of the considered control system. In this case, the risk of damage of individual components of the system during the tests is eliminated because of its virtual nature. The “virtual starting” of the machine should be related with the logic of the program of PLC. The integration of the virtual model of the control system with the virtual controller enables introducing the mechatronic design concept to the process of machine designing. In the Institute of Process Automation and Integrated Manufacturing Systems, a number of work is being carried out on the design and verification of control systems [1-16] and the integration of different program environments [17-24].

The main research area for the integration of the virtual model of the designed mechatronic system with the virtual controller is the use of dynamic data exchange (DDE) as well as the ActiveX technique. The mentioned above techniques of integration allow conducting verification of the operation of the designed actuating system of the analyzed machine (according the assumed motion sequence), determining the dynamic work space of the system, visualizing the process already at the conceptual phase of the design process as well as verifying the program for the controller. This paper presents the method of integrating the virtual model of a pneumotronic control system with a virtual controller using the integrator in the form of an OPC server.

2. Designing the sequence control system using the algorithmic method

The considered mechatronic system is consisted of a machine that divides and groups the workpiece. One of the main subsystems of the machine is the sequential control one. The actuating subsystem of the proposed control system consists of three servo-motors of a linear motion (Figure 1). The cycle of work of the control system is described using the function diagram. In the initial state, all actuators of the system take their rear end positions (the actuators are retracted). Once the process is initialized, the actuator A (actuator pushing workpieces) is extended first, which pushes the elements from the gravity store and then returns to its starting position. Then the actuator B (workpieces grouping actuator) executes the movement, which is responsible for grouping the elements. At this phase of the system operation, the actuator B moves to its extreme front position and positions the object. In the next step, the actuator B returns to its starting position. Subsequently, the actuator A ejects the second element from the gravity magazine and returns to its original position. In the next step, the actuator B moves by half its stroke and positions the second element. After the return of the actuator B to the starting position, the actuator C (actuator inserting workpieces) moves elements to the machine tool system.

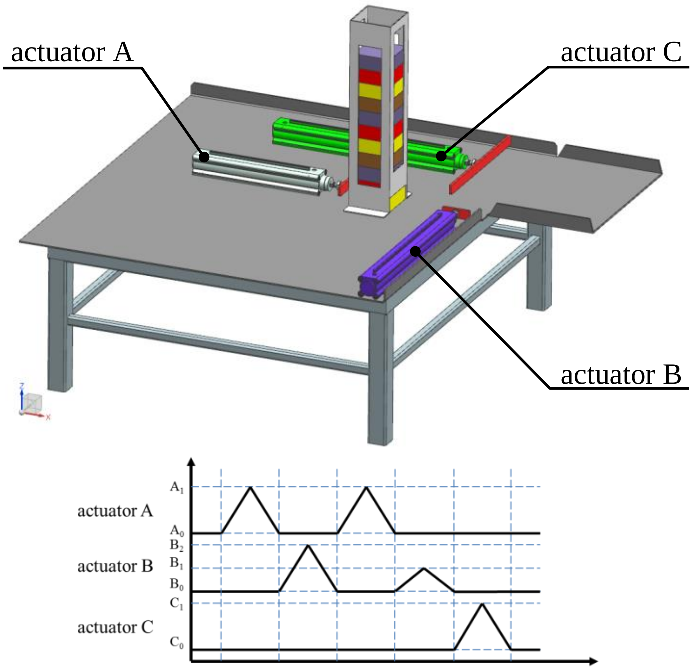
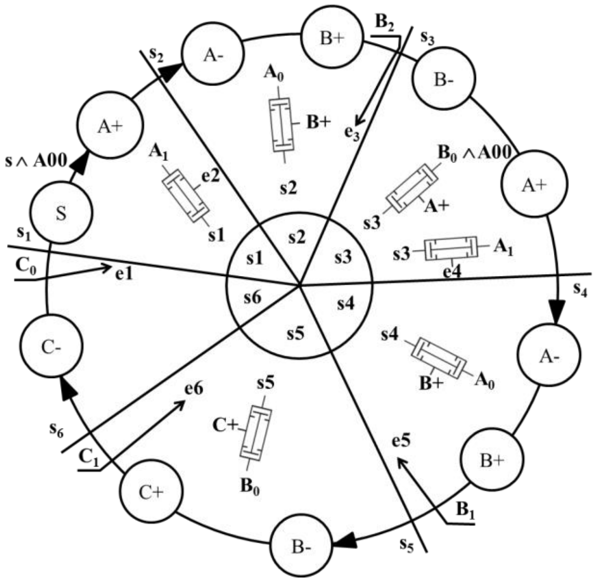


Figure 1. The virtual model of the actuator system.

The travel of the servo-motors of the machine for dividing and grouping elements, have been selected to ensure that the machine could properly co-operate with the other components of the technological system. The selected actuators are characterized by the following travels:

- 300 mm with respect to the actuator A - due to the dimensions of the transported element, which is in the gravity store,
- 500 mm with respect to the actuator B - due to the correct placement of the components before they are inserted into the machine, which is determined by the geometrical form of the clamping system in the machine tool,
- 500 mm with respect to the actuator c - due to the correct movement of the components between the dividing and grouping machine and the machine tool.

The field of the problem is related to verification of the operation of the actuator system of the electropneumatic control system with a PLC controller. To verification is subjected the manner in which the actuators operate according to the adopted cycle of the grouping device. In order to develop the logical relationships that describe the work cycle of the device, an algorithmic method of designing the pneumatic sequential control systems was utilized [25, 26]. The method was then adapted to create the logic of the electropneumatic control system being considered. According to the adopted design method in the pneumatic control system was used actuators in the form of two-way pneumatic cylinders, signal elements in the form of two-position three-way valves controlled by a roll, the adjusting elements in the form of two-position four-ways valves, pneumatically controlled, the control elements in the form of air flow controlling valves. Basing on the adopted components of the control system and the function diagram, describing the operation of the system, a signal flow graph was created (figure 2).



$$(s \wedge A00) \vee (s3 \wedge B_0 \wedge A00) \rightarrow A+$$
$$s2 \vee s4 \rightarrow A-$$
$$(s2 \wedge A_0) \vee (s4 \wedge A_0) \rightarrow B+$$
$$s3 \wedge s5 \rightarrow B-$$

Figure 2. The flow graph of signals, which describe the logic of operation of the designed system.

The graph logically reflects the expected sequential action of the motion of the actuators of the control system. The graph shows the following signals:

- s1 to s6, which represent the output signals of the clock unit,
- e1 to e6, which represent the input signals of the clock unit,
- A_0, A_1, B_0, B_1, B_2, C_0, C_1, which represent the states of actuators (cylinders) of the control system (A_0, B_0, C_0 – means the retracted cylinder; A_1, B_2, C_1 – means the extracted cylinder; b1 – means the actuator is set to half its stroke value),
- A00, which represents the presence of the moving item in the gravity store,
- s, which represents the signal of start of the working cycle of the grouping machine.

Signals of the graph A_0, A_1, B_0, B_1, B_2, C_0, C_1, are associated with its edges and represent the signal elements of the control system that receive output signals of the clock unit (si, i = 1..6) in the given clock cycle. These signals also allow switching the clock cycle of the clock unit by tuning the signal e1 to e6. The idea of the clock unit is based on such control process in which one clock cycle could be executed at the same time. And in a given cloak cycle, any actuator could change its state only once. The expected state of the actuators (A +, B +, C +, A-, B-, C-) of the control system is related to the vertices of the graph ("+" - means that the actuator is extended, "-" - means that the actuator is retracted) and concerns the setting elements of the system. In the graph of the signals flow the logic elements "AND" and "OR" also are used. The logic elements "OR" are used when at least two different signals cause the same state of the expected operation of actuators. Hence the logic element "AND" is used when the signal representing the given state of the actuator (e.g.: A_0) occurs at different clock cycles and causes different actions of the actuators. Basing on the developed graph, the logical structure of the pneumatic control system using the clock unit was developed first (figure 3).

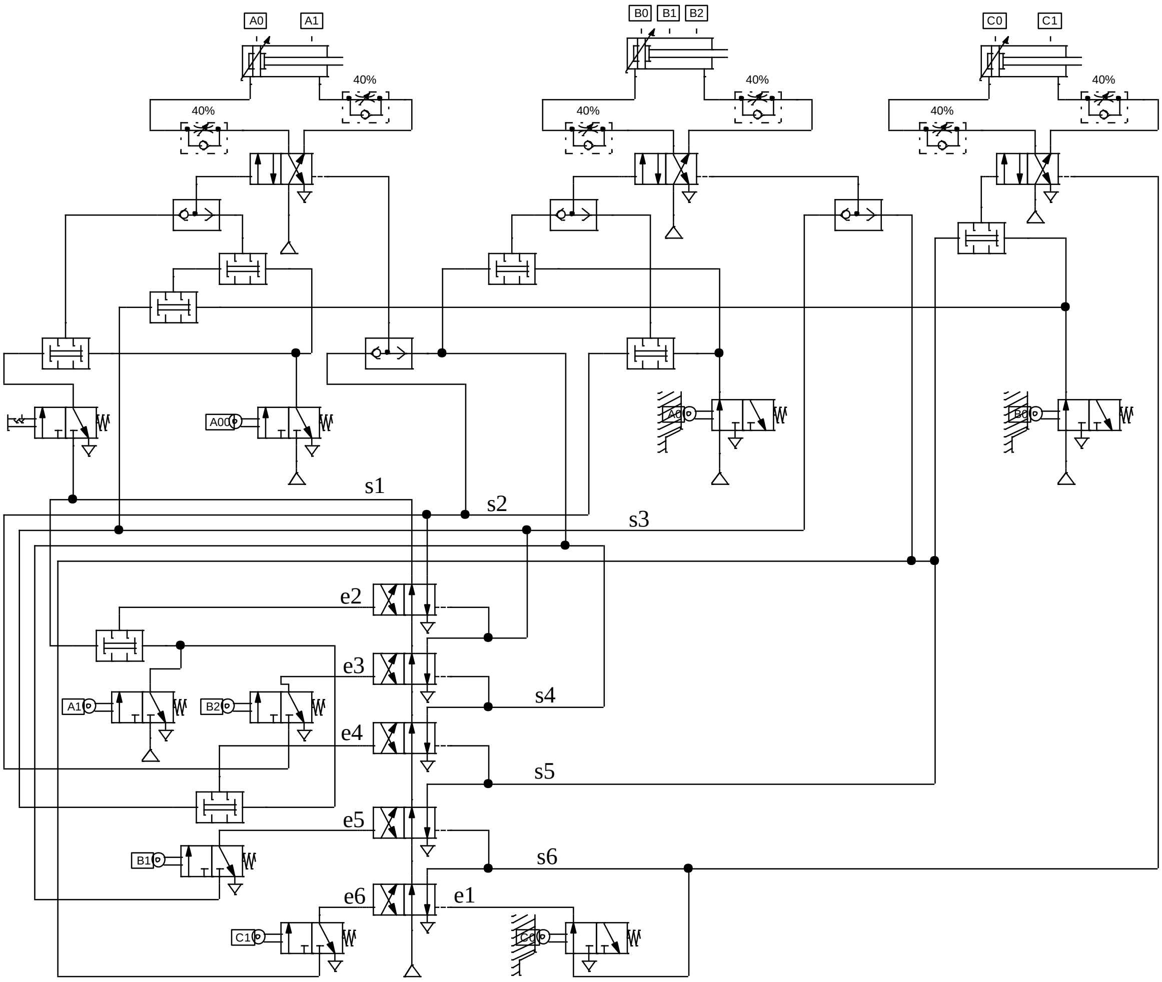


Figure 3. Virtual model of the sequence pneumatic control system.

Then on this basis the logical structure of the electropneumatic control system was developed. In this case were used, the actuators in the form of double acting pneumatic cylinders, signal elements in the form of two-position three-way roller controlled valves, setting elements in the form electrically controlled two-position four-way valves, and control elements in the form control valves controlling the air flow intensity (figure 4). In the electropneumatic control system, the solution of the clock unit was achieved using a serial connection of contacts of relays k1 to k6. Relay contacts are treated as output signals from the clock unit. On the other hand, the power supply of the relay is treated as an input to the clock unit that switches its state (clock cycle). Switching the state of the clock unit causes that all other clock cycles become inactive.

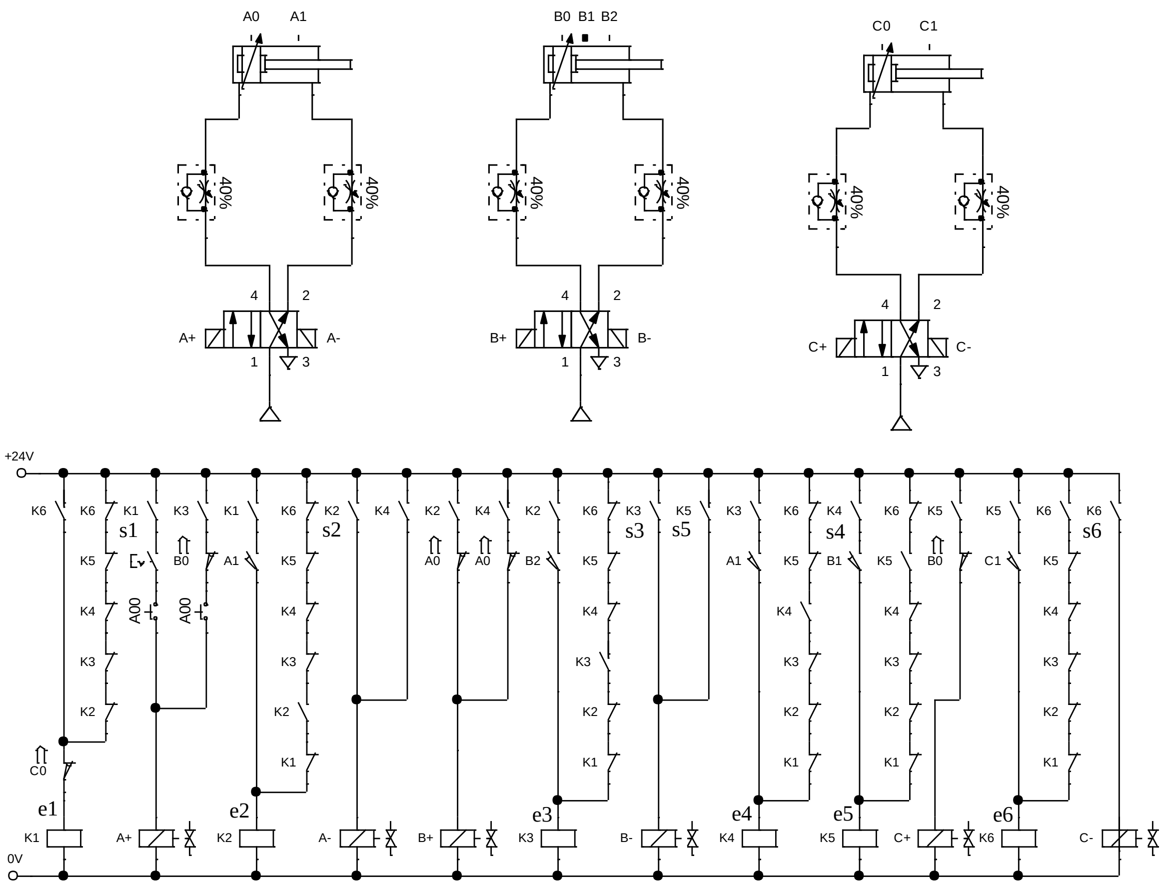


Figure 4. Virtual model of the sequence electropneumatic control system.

The created virtual models of the control system of the grouping machine reflect its assumed operation logic. The operation logic describe as the scheme of the electropneumatic control system is the basis for the proper programming of the virtual controller.

3. Integration of the virtual model of the actuator system with the virtual controller

In order to simulate the mechatronic function of the described system it is necessary to develop a method of integrating a virtual controller with a virtual model of the control system. In this case, an OPC server was used as an integrator, allowing data exchange between the integrated environments. Wherein, information about the state of the object being examined is transferred from the virtual model of the control system to the virtual controller. The virtual controller, based on the implemented logic structure, processes the acquired data and generates execution signals for the model of the control system (figure 5). The virtual model of the control system was created in the FluidSIM software. Whilst the tested logic of the electropneumatic control system has been implemented in the Automation Studio software of the B&R firm. The OPC BR.OPC.Server_3.0_V1.14.19 server was used to integrate both program environments. Transmitting the information about the state of the control system to the OPC server (actuators position) is done via the "FluidSIM Output Port" component to which the signal elements of the system are connected. The "FluidSIM Input Port" component, on the other hand, allows transferring signals from the OPC server that cause the sequential operation of the actuators of the system.

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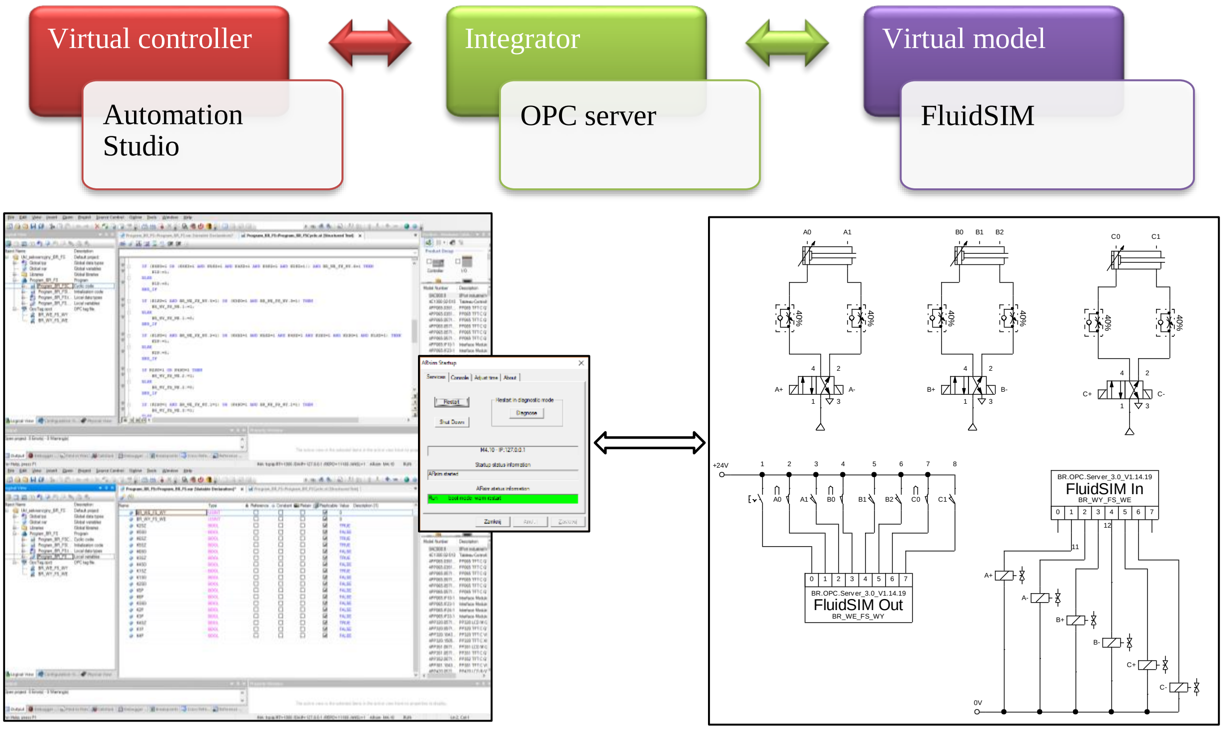

Figure 5. Integration of the virtual model of the actuator system with the virtual controller.

The control program, created in the virtual controller, was written in the “Structured text” programming language. In order to implement the clock unit in the program were defined the variables representing the relays (K1P, K2P, K3P, K4P, K5P, K6P of the “BOOL” type) to which an initial value set to “FALSE” is assigned. The normally open contacts of the relays (K1SO, K2SO, K3SO, K4SO, K5SO, K6SO of the “BOOL” type) have been defined with the initial value set to “FALSE” and the normally closed contacts (K1SZ, K2SZ, K3SZ, K4SZ, K5SZ, K6SZ of the “BOOL” type) with the initial value set to “TRUE”. Next were defined the rules designated to ensure the sequential operation of the virtual control system and the variables responsible for communicating with the OPC server. For this purpose, the variables of the “USINT” type were defined (8-Bit unsigned integer with a range from 0 to 255) with the names BR_WE_FS_WY and BR_WY_FS_WE. The BR_WE_FS_WY variable retrieves, via the OPC server, data concerning the state of the virtual control system. Whilst the BR_WY_FS_WE variable transmits, via the OPC server, the control signals to the virtual model of the control system.

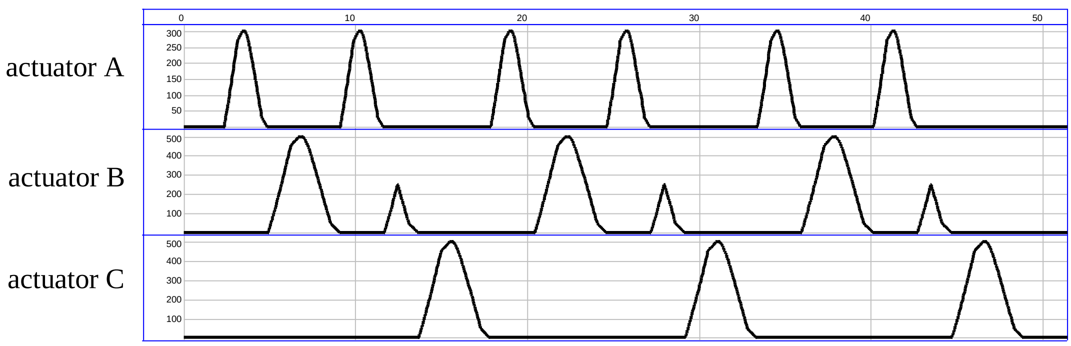

Figure 6. Cyclogram of work of the pneumotronic control system of the grouping machine.

After integrating the virtual model of the control system with the virtual controller, a number of analyzes were performed to verify its operation at different values of the system parameters.

Table 1. Basic parameters of work of the control system.

Parameter	**Value**
Diameter of piston of A, B, C actuators	32 mm
Diameter of piston rod of A, B, C actuators	12 mm
Stroke of A actuator	300 mm
Stroke of B and C actuators	500 mm
Mass of the shifted element	0.5 kg
Working pressure	0.6 MPa
Air flow intensity	50 l/min

The main objective of the analysis was to obtain such a cycle of work of the system that in less than one minute the system could perform 3 full cycles of its work. The timing of operation of the pneumotronic control system, shown in figure 6, was obtained with the values of the basic parameters of the system shown in table 1.

4. Conclusion

The integrated approach of two programming environments allows verifying the logic structure of a program for the PLC controller taking into consideration the assumed operating of a machine.
The algorithmic method of designing the pneumatic and electropneumatic sequential control systems could be used, on the basis of analogy, to create a control program for a virtual controller.
The process of designing of an integrated control system model is held in accordance with the mechatronic design method (inseparably from the virtual controller). Due to the introduced coupling between the systems being under consideration, it is possible to study the influence of changes in parameters of the system model and the control program on the control system functioning. The application the integrator, in the form of the OPC server, enables the exchange of signals between the virtual model of the control system and the virtual controller.
Basing on the conducted analyzes, the basic parameters of the actuators of the control system were selected. These actions allowed determining the number of clock cycles of machine operation in the assumed time interval.

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