Designing an on-board computer for an armored personnel carrier

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Abstract. Timely and accurate solution of the tasks facing the Russian Guard is impossible without a good state of military equipment. The Kupol monitoring system used by the Russian Guard is intended only for monitoring the location of mobile objects using GLONASS / GPS satellite navigation systems, for transmitting navigation information over mobile radio communication networks. Currently, the condition of the armored personnel carrier (BTR-80) is monitored periodically, in accordance with the maintenance regulations. However, the condition of an individual vehicle may differ from the average armored personnel carrier, and therefore it became necessary to re-equip the BTR-80 with an on-board computer that accurately diagnoses the wear (serviceability) of equipment and the combat capability of the vehicle's units. There is a functional connection between the structural parameters and the parameters of the output processes, due to which, according to the parameters of the latter, it is possible to adequately assess the technical state of military equipment (unit), as well as the quality of its work. The nominal parameters of the structural parameters correspond to the nominal parameters of the parameters of the output processes. As the technical state of military equipment (unit) shifts to the worse, the parameters of the output processes can increase (fuel consumption, vibration) or decrease (oil pressure in the engine). The designed monitoring systems of the BTR-80 are grouped by the type of tasks performed or the drive mechanism: engine and transmission, radio communication, electrical equipment, pneumatic systems, hydraulics, and others. The design of the on-board computer is performed on a programmable logic device using the international standard IEC61131-3. The simulation of the relay-contact circuit showed positive results.

1. Introduction
The history of the first on-board computers goes back to the 1980s [1-3]. Currently, on-board computers and computer technologies are widely used in many transport areas [4-7]. The implementation of automation tools for military equipment is also an urgent task. Currently, the rolling stock of Rosgvardiya is being modernized. The problem of control and combat readiness of military equipment is acute in all units of Rosgvardiya. For use in Rosgvardiya, a monitoring system “Dome” has been
developed, which serves as a database and analysis of the combat capability of military equipment. But the current state of each individual unit of military equipment needs additional detail. Periodic technical inspection of military equipment is insufficient, and therefore the development of an on-board computer for an armored personnel carrier is an urgent task. To transmit readings from individual components and mechanisms, various mechanical sensors are used, which very quickly become worn out, and some equipment does not have monitoring tools. For monitoring the condition of military equipment, it is necessary to develop tools for analyzing the components and mechanisms of the machine. On the object under study (an armored personnel carrier) the transmitted information is the parameters of the power unit (temperature, engine oil pressure, turbocharger operation, the condition of the transmission shafts), the operation of the pneumatic and hydraulic systems, the battery voltage, the operation of the generator unit, and other parameters. There is a need to improve the transmission of data from the nodes and mechanisms of the equipment to the control and measuring devices.

2. Equipment and devices used in studies
The research used the theory of finite automata, the theory of constructing relay-contact circuits. The software and hardware is implemented on the Omron PLC and the NT-21 touch screen monitor.

3. The results of the study and their discussion

3.1. Purpose of automated monitoring means of the military equipment condition
During diagnostics, to assess the technical state of military equipment (unit), the output processes of the functioning mechanism are used. Work output processes are distinguished (fuel consumption, power consumption or output, heat exchange with the external environment) and related ones (vibration, noise, light phenomena, etc.). All output processes are quantitatively assessed using the appropriate parameters (power output can be assessed by the corresponding value and the rate of its increase). Depending on the amount of data that contains the parameters of the output processes, they can be private or generalized. The former characterize the technical condition of a particular unit of the system (knocks in the engine crank mechanism, steering wheel play, etc.), the generalized ones characterize the technical condition of military equipment (unit) as a whole (fuel consumption per 100 km of track, path and acceleration time of military technique up to a given speed, etc.). The parameters of the output processes, in contrast to the structural ones, are most often calculated on operating military equipment and are used to identify its technical condition without disassembly.

3.2. Composition of diagnostic modules
At the object under study (armored personnel carrier (APC), the transmitted information is the engine temperature, the operation of the turbocharger, the condition of the gearbox shafts, the voltage of the battery, the operation of the generator unit, the operation of special equipment and other parameters. There is a need to improve the transmission of data from units and mechanisms of equipment to the control and measuring devices. We divide the technological parameters of the equipment into the next groups. The group (Engine, transmission) will be described by the function MT (P, T, Tax, TK, 1D, 2D, C, F). The group (Electrical equipment) will be described by the array E (U, I, O1, O2, O3, O4). The group (Pneumatic system) will be described by the function PS (P1, P2, P3). The group (Radio communication unit) will be described by R (R1–R6). The values of the variables are given in table 1.
Table 1. Monitoring of the current values of the measured parameters and limit values was recorded in the Data Memory cells.

| N  | Bit address | Value | Memory address DM | Monitoring object          |
|----|-------------|-------|-------------------|---------------------------|
|    | CIO         |       | current           | max | min       | Engine, transmission |
| 1  | 100.00      | P     | 100               | 105 | 104       | Oil pressure         |
| 2  | 100.01      | T     | 90                | 95  |           | Antifreeze temperature |
| 3  | 100.02      | Tax   | 80                | 85  |           | Tachometer           |
| 4  | 100.03      | TK    | 70                | 75  | 74        | Turbocharger         |
| 5  | 100.04      | 1D    | 60                |     |           | Transmission         |
|    |             |       |                   |     |           | Input shaft sensor   |
| 6  | 100.05      | 2D    | 55                |     |           | Transmission         |
|    |             |       |                   |     |           | Output shaft sensor  |
| 7  | 100.06      | C     | 54                |     |           | Clutch malfunction   |
| 8  | 100.07      | F     | 50                |     |           | Injectors            |
| 9  | 100.10      | MT    |                   |     |           | General section diagnostics |

| N  | Bit address | Value | Memory address DM | Monitoring object          |
|----|-------------|-------|-------------------|---------------------------|
|    | CIO         |       |                   |                           | Electrical equipment    |
| 10 | 100.11      | U     | 40                | 44 |           | Battery voltage       |
| 11 | 100.12      | I     | 30                | 35 | 34        | Recharging current    |
| 12 | 100.13      | O1    | 20                |               | Dimensions            |
| 13 | 100.14      | O2    | 15                |               | Low beam              |
| 14 | 100.15      | O3    | 14                |               | High beam             |
| 15 | 100.16      | O4    | 16                |               | Stop-signal           |
| 16 | 101.13      | E     |                   |               | General section diagnostics |

| N  | Bit address | Value | Memory address DM | Monitoring object          |
|----|-------------|-------|-------------------|---------------------------|
|    | CIO         |       |                   |                           | Pneumatic system        |
| 17 | 101.00      | P1    | 10                | 15 | 14        | Total pressure        |
| 18 | 101.01      | P2    | 110               | 115 | 114       | Tire pressure         |
| 19 | 101.02      | P3    | 120               |               | Brake system          |
| 20 | 101.12      | PS    |                   |               | General section diagnostics |

| N  | Bit address | Value | Memory address DM | Monitoring object          |
|----|-------------|-------|-------------------|---------------------------|
|    | CIO         |       |                   |                           | Radio communication unit |
| 21 | 101.03      | R1    | 130               |                           | Receiver-transmitter    |
| 22 | 101.04      | R2    | 140               |                           | High-frequency pulse generator |
| 23 | 101.05      | R3    | 150               |                           | Antenna filter block    |
| 24 | 101.06      | R4    | 160               |                           | Laryngophone amplifier  |
| 25 | 101.07      | R5    | 170               | 175 | 174       | RF cable              |
| 26 | 101.08      | R6    | 180               | 175 | 174       | Voltage transformer   |
|    | 101.14      | R     |                   |                           | General section diagnostics |

3.3. Compilation of logical equations and development of software for the equipment operation
Logical equations for monitoring the “Engine, transmission” section are shown in table 2.

Table 2. Logical equations for monitoring the “Engine, transmission” section.

| Logical equations | Equipment          |
|-------------------|--------------------|
| \((DM_{100} < DM_{105}) \cdot (DM_{100} > DM_{104}) = P\) | Oil pressure       |
| \(DM_{90} < DM_{95} = T\) | Antifreeze temperature |
| \(DM_{80} < DM_{85} = Tax\) | Tachometer         |
\[(DM\ 70 < DM\ 75) \cdot (DM\ 70 > DM\ 74) = TK\]
\[DM\ 60 > 0 = 1D\]
\[DM\ 55 > 0 = 2D\]
\[\frac{DM\ 54}{DM\ 50} = \frac{C}{F}\]
\[P \cdot T \cdot Tax \cdot TK \cdot 1D \cdot 2D \cdot C \cdot F = DT\]

Turbocharger
Transmission
Input shaft sensor
Transmission
Output shaft sensor
Clutch malfunction
Injectors

Using the example of table 2, logical equations were developed for all sections (table 1). Researching the model for monitoring and controlling the equipment condition were carried out using the OMRON CX-Programmer and CX-Designer software [8,9]. The programming language of the OMRON CP1L controller was ladder-contact logic (the IEC 61131-3 standard). A simulation of the operation of the circuit using the example of monitoring oil pressure and engine speed is shown in figures 1 and 2.

**Figure 1.** Simulation of the circuit. Engine oil pressure is within normal limits. All monitoring units of the “Engine, transmission” operate normally.

**Figure 2.** The tachometer showed dangerous engine speed, the general circuit of the section went into a warning state.

### 4. Conclusion

For monitoring the military equipment condition, using the BTR-80 as an example, an on-board computer based on the OMRON programmable logic controller has been developed. The equipment monitoring is shown, divided into 4 sections, including about 30 positions. In the future, it is possible to expand the monitoring nodes and refine the software. A simulation of the circuit has shown satisfactory results.
References

[1] Sharma U K and Mc Tamaney L S 1987 Real time system architecture for a mobile robot Proceedings of SPIE - The International Society for Optical Engineering 852 25-31

[2] Harland D B 1983 A simple model of a car suspension system using an analogue computer Teaching Mathematics and its Applications: an international journal of IMA 2(2) 79

[3] Oliveira A G et al. 2021 A Look at the Evolution of Autonomous Cars and Its Impact on Society Along with Their Perspective on Future Mobility Smart Innovation, Systems and Technologies 201 583-94

[4] Zhou L, Dang J and Zhang Z 2021 Research on fault diagnosis for on-board equipment of train control system based on imbalanced text classification Journal of Applied Science and Engineering (Taiwan) 24(2) 167-75

[5] Samoïlenko A P, Panychev A I and Panychev S A 2017 Technologies of aggregation for integral criteria of evaluating the efficiency of on-board computer systems RPC 2017 - Proceedings of the 2nd Russian-Pacific Conference on Computer Technology and Application 157-61

[6] Popkov A and Bekher S 2018 Use of computer software for technical training at rail car repair shops MATEC Web of Conferences. 10th International Scientific and Technical Conference "Polytransport Systems" 04001

[7] Bukowski M, Luckner M and Kunicki R 2020 Estimation of free space on car park using computer vision algorithms Advances in Intelligent Systems and Computing 920 316-25

[8] Kostarev S N and Sereda T G 2017 IOP Conf. Ser.: Earth Environ. Sci. 87 032016

[9] Kostarev S N et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 537 032030