Archives of
Transport System
Telematics

Volume 12

Issue 2

May 2019

Simulation of Digital Interfaces for Railway Traffic Control Systems Using IBIS Models

R. PNIEWSKI, M. KORNASZEWSKI
UNIVERSITY OF TECHNOLOGY AND HUMANITIES IN RADOM, Malczewskiego 29, 26-600 Radom, Poland
EMAIL: r.pniewski@uthrad.pl

ABSTRACT

Currently used, computer railway traffic control systems , communicate via standard digital interfaces: CAN, Ethernet or RS485. In order to carry out the proof of security, it is necessary to test the functioning of the interfaces under different conditions. The IBIS model (I/O Buffer Information Specification) was used to simulate the transmission of signals through interfaces. The article discusses the applied interface models and simulation results in various conditions. The presented results can be used to prove the safety of transmission in computer railway traffic control systems.

KEYWORDS: Traffic control system, digital interface, simulation

1 Introduction

The experience of recent years has confirmed that insufficient development of transport infrastructure is one of the most important factors that hamper the development of Poland. Transport activities are geared towards single short-term objectives and, as a consequence, lack a long-term vision for development. The source of these problems is, first of all, the deficit of the substantive factor in the decision-making process [13-15].

he scientific community has repeatedly expressed its willingness to take part in a substantive discussion on transport policy. With real intellectual capital, which in addition to specialist knowledge is also independent of political factors, we are able to significantly enrich this discussion and ensure that the designed strategies and decision-making processes are based on knowledge and factual elements. Only such an independent look will guarantee the development of a policy that is oriented towards the achievement of long-term goals and allows to eliminate cyclical breakdowns in the functioning of transport. Only a modern and creative perception of transport problems will enable a dynamic and effective development of this area.

More than ten years of operation of the Polish railways after Poland's accession to the EU led to liberalisation, but it did not remove significant problems hampering its sustainable development. Ensuring the openness of the railway market in Poland and its sustainable development will be possible if railway companies are treated systematically and programmes developed over a multi-annual cycle are implemented. From the legal point of view, Poland has implemented a number of acts adapting the railways to the EU requirements. The basic problems, which were clearly visible in the initial phase, are still unresolved. These include, but are not limited to:

- problems with the independent management of railway infrastructure
- efficiency of infrastructure management
- open access to infrastructure for all operators
- financial imbalance in new investments and modernisation of the existing railway network
- high underinvestment in passenger traffic
- unreasonable rates of access to railway infrastructure
- unhealthy competition between certain operators
- low level of customer service

- lack of sufficient support from the Ministry of Infrastructure and Rail Transport Development
- lack of multiannual investment programmes (long-term contracts) agreed between the government, parliament and PKP PLK
- lack of consistency in the implementation of existing programmes (e.g. ERTMS / GSM-R)
- low quality or lack of strategic state documents concerning the development of the transport infrastructure of Poland as a whole

Research and didactic process conducted in the Department of Control Systems in Transport of UTH in Radom fit perfectly into the presented strategy of activities.

The aim of the research work carried out in the ZSSwT was to develop an automatic data acquisition system and an expert system for applying for the condition of equipment. This goal will be achieved through the development of methods of analysis of diagnostic data of railway traffic control devices.

The aim of the project has been achieved through:

- construction of a new research laboratory for traffic control devices (and integration with the existing laboratories in the Faculty),
- construction of an automatic system for collecting data on the condition of equipment,
- construction of a reliable model of railway automation equipment,
- collection and preparation of data concerning railway traffic control systems,
- preparation of means of simulating typical and emergency working conditions of railway traffic control systems,
- preparation of a database for gathering information about railway traffic control systems,
- preparation of procedures for determining the characteristics.

The expert system use contains basic data on the use processes of railway traffic control systems and their reliability and renewal for six main modules (railway traffic control subsystems):

- a general description of the technical, operational and economic characteristics,
- linear locking devices,
- setting devices,
- level crossings signaling,
- track-vehicle interaction devices,
- remote control devices.

The structure of the expert system developed at the Faculty of Transport and Electrical Engineering is shown in Fig. 1.

The results obtained on the basis of operational tests and on-going diagnostics of railway traffic control systems can be used not only as a basis for improving the construction of technical facilities and improving the production process, but also as one of the possibilities of obtaining reliable information necessary to control the exploitation process, including renewal, proper organization of maintenance and repair facilities, or forecasting and determination of operating costs. One of the basic objectives of the implemented project was the construction of an automatic system for collecting data on the condition of equipment. This activity required the development of diagnostic interfaces, the connection of which does not reduce the safety of the diagnosed railway traffic control systems [2, 3, 7, 9, 11].

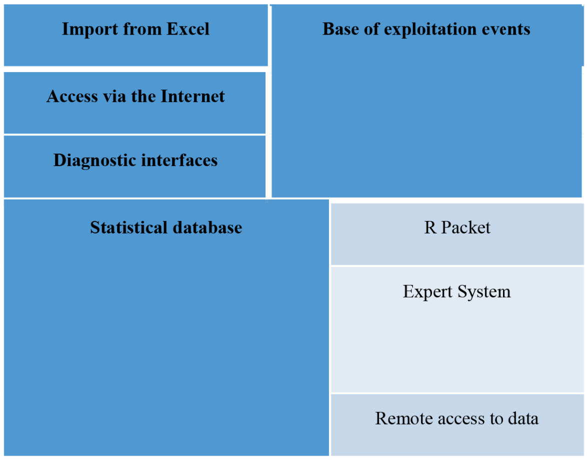

Fig. 1. Structure of the expert system [own study]

2. Digital interfaces for diagnostics of railway traffic control systems

Interfaces are used in railway traffic control systems for data transmission between modules (in internal networks):

1. ETHERNET
2. RS-485
3. CAN
4. SPI

Fig. 2 and Fig. 3 show examples of solutions used by Bombardier and Kombud.

2.1 SZP-1 crossing signalling

The SZP-1 - level crossings signaling system is used to secure category A, B and C crossings on single and double-track lines, both with automatic, semi-automatic and unblocking, where train speed does not exceed 160km/h. SZP-1 is a distributed structure system, where wired and wireless transmission is used for communication [5, 6, 10, 12].

The control subsystem analyses information coming from the interaction equipment subsystem and controls and controls the actuators:

1. traffic signals,
2. horns,
3. travel warning discs.

The control subsystem may also control equipment within the ancillary equipment subsystem. Through the interface ISZ realizes the connection with station systems and ensures cooperation with the devices of remote control of the UZK. Remote control devices are designed for railroad crossings of all categories for which the SZP-1 system is designed. Their role, depending on the category of crossings, is different. In systems of category A, UZK plays a diagnostic role and registers events. Due to the dispersion of the system and the use of radio transmission (less resistant to interferences than wired connections), the following solutions have been applied to the controllers' software:

- no transmission or transmission errors (which is tantamount to the fact that incorrect packets are rejected) cause the devices directly cooperating with these controllers to go to a safe state.
- no transmission for EST_G (no messages from the dependent controllers) causes the orange lights on the TOP warning discs to light up.
- lack of transmission for TSR devices (also in standby mode) results in closing the horns and switching on the traffic signal and the bell.

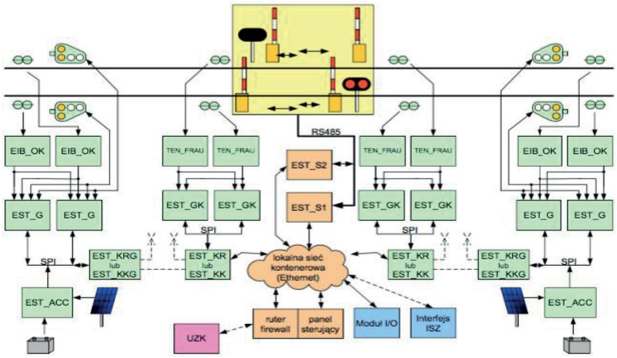

Fig. 2. Structure of the SZP-1 system [6]

2.2 Structure of the SOL-21 system

The SOL-21 type track and turnout obsolescence control system is a set of devices operating on the basis of a dispersed structure, performing all functions of such systems, which consists of a counting unit and wheel sensors connected to each other by means of appropriate transmission links (Fig. 3). Wheel sensors located throughout the entire area of operation of the SOL-21 system are connected to the counting unit by means of appropriate transmission links, through which data on the number of counted axles and additional information necessary for the operation of the system are transmitted. The counting unit, due to its essential importance in the system, can be duplicated by means of an additional counting unit acting as a hot reserve. The SOL-21 system, connected via the Ethernet interface to the railway traffic control system, provides information on the status of individual sections and receives commands to reset the number of axes in sections (only in the electronic interface). Data exchange between the wheel sensors and the counting unit takes place cyclically, which is called the object transmission cycle. Due to the use of two types of transmission: CAN and FSK, there are two types of field transmission support. For CAN, the transmission is initiated by the counting unit by sending a global telegram in each field transmission loop. The wheel sensors correspond to status telegrams containing information on the number of axles counted, sensor malfunctions and diagnostics. The counting unit receives them, checks them for correctness and transmits the data from the telegrams to the axle counting modules. For the rest of the cycle time, the counting unit can send telegrams with commands to the individual sensors, if the axle counting module has prepared such commands on the basis of data from the wheel sensors from the previous transmission cycle.

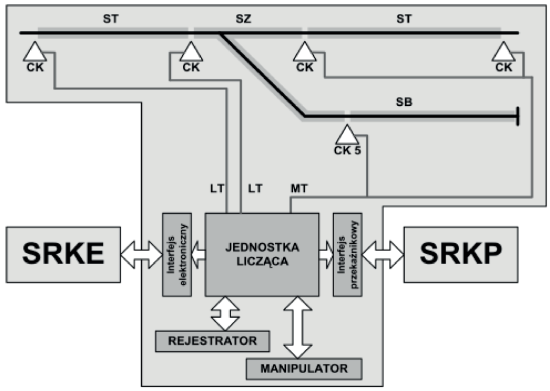

Fig. 3. Structure SOL-21 system [1]

Fig. 4 shows the connection of the developed diagnostic interfaces to railway traffic control systems installed in laboratories of the University of Technology and Humanities in Radom [4].

Fig. 4. Connection of diagnostic interfaces in UTH laboratories [own study]

2.3 Diagnostic interfaces that do not compromise system safety

Ethernet

Ethernet was developed in 1976 by Xerox and then developed by the DIX consortium (Dec, Intel, Xerox). The idea of network is based on the idea of nodes connected to a common medium. Individual modules send and receive special messages (frames). This method of communication is called CSMA/CD (Carrier Sense Multiple Access with Collision Detection) [8].

The following standards are currently used in ETHERNET networks:

1. 10Base-T - uses two pairs (4 wires) of category 3 or 5 UTP cables. It transmits the signal in segments with a maximum length of 100 meters. One pair transmits and the other receives.
2. 100Base-TX - similar to 10BASE-T, but at 100Mbps. It requires 2 pairs of category 5 twisted-pair cables. Currently, one of the most popular twisted-pair network standards.
3. 1000BASE-T - 1 Gbps on cat. 5 or higher twisted pair cable. Since category 6 cable can transmit up to 125 Mbps without losses, achieving 1000 Mbps requires the use of four pairs of cables and

modification of transmission systems to allow for transmission of about 250 Mbps per pair of cables in the twisted-pair cable.

The first two are used in SRK systems. The following functions have been implemented in the developed prototype of the exploitation data processing module:

1. reading data from systems (UTP protocol),
2. preliminary analysis of the correctness of the data,
3. data encryption,
4. sending processed data (TCP/IP protocol).

Safety of the system to which the interface is connected is ensured by physical (hardware) cutting off the transmitting line (TR+ and TR-). This solution guarantees that the connected diagnostic module will not send data to the system, which could cause its malfunction (railway traffic control systems respond correctly to transmission fades). Thanks to the hardware transmission safety assurance, the change of the diagnostic module's software will not require any safety analysis after the software change.

RS485

The RS-485 standard was introduced in 1983 as an extension of the RS-422A standard. The RS-485 interface is symmetrical and balanced (i.e. a symmetrical and differentiated circuit is a two-wire circuit in which cables and their connected circuits have the same impedance to the ground as to other cables). Not only many receivers are allowed, but also many transmitters connected to one line. Transmitters must be tri-state because only one of them can transmit in a given period of time, and the others must be switched off. When no data transmission takes place, all transmitters are switched off, during transmission one transmitter determines the status of the line and all receivers can receive the transmitted data. The standard allows up to 32 transmitters/receivers to be connected to the line, it is possible to connect more devices to the line by using appropriate signal regenerators. Limitation of the number of devices connected to the transmission line results from the permissible load of this line. Fig. 5 shows how to connect devices to the RS-485 bus. To diagnose devices connected to the RS-485 interface, the SN75107 system was used (the internal structure of which is shown in Fig. 6). It is a standard symmetrical line receiver. System parameters, especially propagation times and input currents are more advantageous than the parameters of systems dedicated for this interface. Connecting the receiver's inputs through resistors with a value of a few kW guarantees safety and correct operation of railway traffic control systems even in the event of receiver damage (the resistors used ensure "isolation" of the interface from the bus).

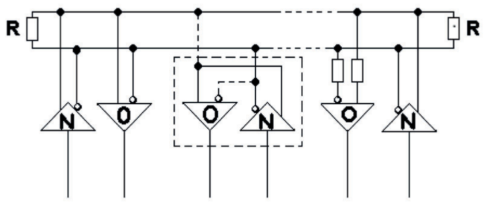

Fig. 5. Connecting transmitters and receivers to the RS-485 network [own study]

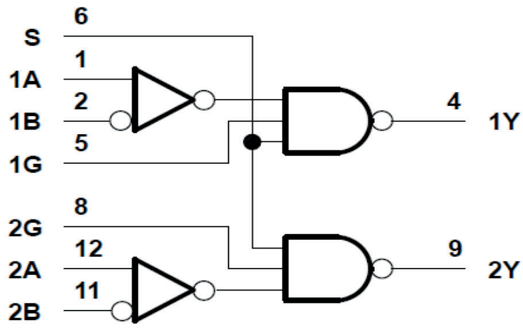

Fig. 6. Internal diagram of SN75176 circuit [16]

CAN

CAN technology, which owes its popularity mainly to automotive applications, is now more and more often used in other transport systems and industrial plants. The CAN bus connects control and executive devices, as well as it is used to establish communication between sensors, controllers and recording systems. Due to the growing popularity of CAN, numerous works are being carried out in order to increase the efficiency of this bus and facilitate its implementation in the industry.

CAN (Controller Area Network) technology, which Bosch developed in the 1980s for in-vehicle communications, is the standard for multiplexed serial bus. The original goal was to improve the functionality and simplify the complex cabling used to transfer data between electronic devices in cars. CAN is based on the mechanism of identifying the messages sent according to their content and not, unlike other bus systems, according to the address of the transmitting or receiving node. In other words, communication is publicity, and network nodes receive and process messages based on their importance and priority. This type of addressing increases the flexibility of the CAN system, allowing for easy addition of new devices to existing networks without the need for additional devices or software modifications. The above, as well as other features of CAN made it move from the position of a vehicle bus to a technology popular in industry and defined by the international standard ISO 11898. As shown earlier, the CAN interface is widely used for the connection of railway automation subsystems.

Fig. 7. shows the way developed by the authors to connect the diagnostic interface to the CAN bus. The proposed solution does not reduce the safety of systems connected to the bus.

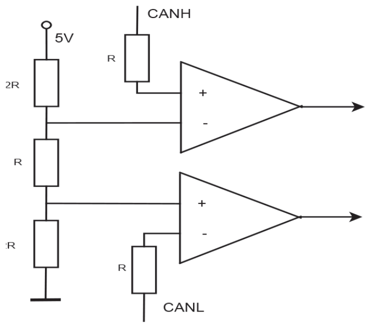

Fig. 7. Connection of the diagnostic interface to the CAN bus [16]

3. IBIS models

IBIS is a behavioral model that describes the electrical characteristics of the digital inputs and outputs of a device through V/I and V/T data. An IBIS model consists of tabular data made up of current and voltage values in the output and input pins, as well as the voltage and time relationship at the output pins under rising or falling switching conditions. This tabulated data represents the behavior of the device [17]. IBIS models can be obtained by gathering data in simulations, or from bench measurements. If the former method is chosen, SPICE can be used to run the simulations and collect the V/I and V/T data for each of the input/output buffers. This allows process corner data to be included in the models. Then, using one of the SPICE-to-IBIS conversion programs available from the IBIS website, the IBIS model can be generated from SPICE. The output IBIS model (for the circuit shown in Fig. 7) is characterized by the following dc electrical data, ac or switching data, and parameters:

1. Pull-Up and Pull-Down Curves
2. Power and GND Clamp Curves
3. Ramp Rate
4. Rising and Falling Waveforms
5. C_Comp
6. Package Parameters

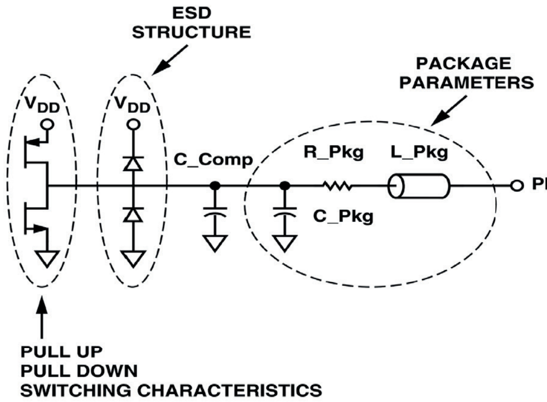

Fig. 8. Three-State Output Buffer [17]

Pull-Up and Pull-Down Curves

The pull-up and pull-down data define the drive strength of the device. These curves are obtained by characterizing the two transistors in the output. The pull-up data describes the I/V behavior when the output is in a logic high state (PMOS transistor on).

Power and GND Clamp Curves

These curves are generated when the output is in a high impedance state.

Ramp Rate and Switching Waveforms

The ramp rate (dV/dt) describes the transition time when the output is switching from the current logic state to another logic state. It is measured at the 20% and 80% points with a default resistive load of 50 W.

C_Comp

This is the silicon die capacitance and does not account for package capacitance. It is the capacitance seen when looking from the pad back into the buffer. C_Comp is a key parameter, especially for receiver inputs. C_Comp should have a value for each of the different corners, min, typ, and max.

```
[Model] OUT1                    <- MODEL TO BE DESCRIBED
Model_type Output
|
Vref=1.50000V
Rref=50.0000ohms
Cref=2.00000pF                                        <- TIMING TE
Vmeas=1.50000V                                           DIE CAPA
C_comp 3.00000pF 3.00000pF 3.00000pF
|
|
[Temperature Range] 25     NA     NA
|

[Pulldown]                      <- I/V PULLDOWN DATA
|
-3.60000V   -373.560uA      NA    NA
-3.30000V   -373.560uA      NA    NA
-3.00000V   -373.560uA      NA    NA
0.00000V    -373.560uA      NA    NA
...         ...              ...   ...
6.00000V    29.8895mA       NA    NA
6.60000V    30.0423mA       NA    NA
7.20000V    30.1951mA       NA    NA
|
...         ...              ...   ...
|

|
[Falling Waveform]              <- SWITCHING WAVEFORMS
R_fixture = 50.0000
V_fixture = 0.00000
|
0.00000s  1.04159V          NA    NA
560.000ps 1.03353V          NA    NA
...       ...            ...   ...
6.60000ns 15.5525mV         NA    NA
9.98000ns 11.3165mV         NA    NA
|
|
[Ramp]                          <- RAMP RATE
| variable typ min max
dV/dt_r 613.749m/1.89595n   NA    NA
dV/dt_f 841.756m/1.65434n   NA    NA
R_load = 50.0000Ohms
|
[End]
```

Fig. 9. IBIS model [17]

4. Simulation of models

There are different EDA vendors providing simulation tools for IBIS models, and each tool can play a specific role in the simulation. A few of these vendors include:

1. Innoveda, Quad (uses XTK models)
2. Innoveda, Hyperlynx
3. Mentor Graphic, Interconnectix
4. Cadence
5. Avanti Corporation
6. Altera Corporation
7. Microsim
8. Veribest

An interesting possibility is the program that allows you to simulate online on the website: https://www.circuitlab.com. A screenshot with a diagram of a simple RS485 network is shown in Fig. 10.

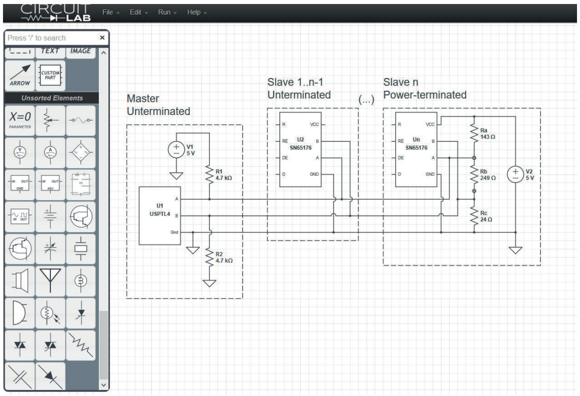

Fig. 8. Three-State Output Buffer [own study]

5. Conclusion

The article presents digital interfaces developed by the authors for diagnostics of computer railway traffic control systems. General information concerning the designed systems is presented, as it is expected that the developed solutions will be patented. Detailed information on the individual interfaces will be presented in the next publications.

Bibliography

[1] Bombardier Transportation (ZWUS) Polska. 2001. Komputerowy system samoczynnej blokady liniowej SHL 12, Dokumentacja Techniczno-Ruchowa, Katowice, 48 s. (in Polish)

[2] CARLSON AH., FRINCKE D., LAUDE MJ.: Railway security issues: A survey of developing railway technology. Proceedings of International Conference on Computer, Communication and Control Technologies (CCCT 03)/9th International Conference on Information Systems Analysis and Synthesis (ISAS03), vol. 1, Inst. Informatics & Systemics, 14269 Lord Barclay DR, Orlando USA, pp. 1-6, 2003

[3] DHILLON B.S.: Transportation Systems, Reliability and Safety. CRC Press 2011

[4] DYDUCH J., KORNASZEWSKI M., PNIEWSKI R.: Nowoczesne laboratorium Systemów Sterowania Ruchem Kolejowym na Politechnice Radomskiej. XV Międzynarodowa Konferencja Naukowa „TRANSCOMP 2011", Zakopane 5-8 grudnia 2011

[5] KORNASZEWSKI M.: Safe computer solutions applied in new generation railway traffic control systems. Computer Systems Aided Science And Engineering Work in Transport, Mechanics and Electrical Engineering. Kasimir Pulaski Technical University of Radom, Faculty of Transport, Radom 2008. ISSN: 1642-5278, pp. 279-284, 2008

[6] KORNASZEWSKI M., PNIEWSKI R.: Bezpieczeństwo komputerowych systemów SRK na przykładzie SZP-1 TTS 9/2012

[7] KUROIWA A., KATO T., KUNIFUJI T.: Improve the safety of maintenance work on the railway using computer. 8th International Conference on Computer Aided Design, Manufacture and Operation in the Railway and Other Advanced Mass Transit Systems (COMPRAIL), Lemnos, GREECE, VOLUME: 13, pp. 915-923

[8] MARSHALL P.S.: Industrial Ethernet: How to Plan, Install, and Maintain Tcp/Ip Ethernet Networks: The Basic Reference Guide for Automation and Process Control Engineers Instrumentation Systems & (1 February 2004)

[9] MIKULSKI J.: Malfunctions of railway traffic control systems - failure rate analysis, 3rd International Conference on Computer Simulation in Risk Analysis and Hazard Mitigation, Sintra, Portugal, Book Series: MANAGEMENT INFORMATION SYSTEMS, Vol. 5, pp. 141-147, 2002

[10] NOWAKOWSKI W., et al.: Failure evaluation of the level crossing protection system based on Fault Tree Analysis, Springer, Cham, Series: Lecture Notes in Networks and Systems: Recent Advances in Traffic Engineering for Transport Networks and Systems, Print ISBN: 978-3-319-64083-9, Online ISBN: 978-3-319-64084-6, pp. 107-115, 2017

[11] PNIEWSKI R.: Metoda oceny bezpieczeństwa cyfrowych systemów automatyki kolejowej. Radom, Wydawnictwo Uniwersytetu Techniczno-Humanistycznego w Radomiu, 146 s., 2013

[12] PNIEWSKI R., KORNASZEWSKI M., CHRZAN M.: Safety of electronic ATC systems in the aspect of technical and operational, Proceedings of the 16th International Scientific Conference Globalization and Its Socio-Economic Consequences, Rajecke Teplice, Slovakia, Part IV, pp. 1729-1735, 2016

[13] PRICEVICIUS G., et al..: Railway Segment Management Information System. Open Conference of Electrical, Electronic and Information Sciences (EStream), IEEE, 345 E 47TH ST, New York, NY 10017, USA, 2016

[14] RENPENNING F., BRABAND J., WERY S.: Application of functional hazard assessment in railway signalling. 14th European Safety and Reliability Conference "ESREL 2003", Maastricht, Netherlands, pp. 1307-1314, 2007

[15] RESTEL F.J., ZAJAC, M.: Reliability Model of the Railway Transportation System With Respect to Hazard States, IEEE International Conference on Industrial Engineering and Engineering Management IEEM, Singapore, SINGAPORE, pp. 1031-1036.

[16] www.ti.com/lit/ds/symlink/sn75176a.pdf [date of access: 12.12.2018]

[17] AN-715 - Analog Devices APPLICATION NOTE