

## THE USE OF CAN IN AUTOMATION TEST BENCH TO TEST THE ENGINE COOLING SYSTEM

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### **Abstract**

*Can is widely distributed network in the industry and automotive applications with high availability enable its electronic components and the easy integration projects with software engineering research Matlab type, tends to encourage the use of these precious features of CAN to build research stands.*

*The article presents a data transmission system using the CAN protocol as a test of a new generation of cooling systems for internal combustion engines. Adopted for the object of research methodology which involves the simulation of variable parameters of the different control strategies require data processing in real time. A large number of recorded and interpreted online information about the temperatures in many parts of the facility and other variables such as instantaneous fuel consumption, secreted mechanical power, crankshaft and throttle position together with the need to control the plant justify departure from the traditional methods of transmitting signals in separate lines, for the application data exchange network, adopted by the authors as a way of organizing the flow of data based on the CAN protocol using the Matlab Simulink Real Time. The article contains a description of the implementation of networks in the context of very specific features for Controller Area Network particularly regarding mechanisms such as arbitration on the bus, the method of initiation and the provision of sufficient transmission capacity. The presented graphs and diagrams illustrate the proposed and implemented solutions and the results obtained from studies measuring temperatures for the warm-up and cooling of the engine.*

**Keywords:** *CAN networks, car networks, data exchange, cooling system, engine operation*

### **1. Introduction**

CAN is a widely distributed network in industry and in automotive applications with a high availability of electronic components to enable its realization and the easy integration with the scientific and engineering software Matlab type, tends to conduct tests using the powerful features of CAN in the construction of research posts.

The article presents a data transmission system using the CAN protocol as a test of a new generation of cooling systems for internal combustion engines. Adopted for the object of research methodology which involves the simulation of variable parameters of the different control strategies require data processing in real time. A large number of recorded and interpreted online information about the temperatures in many parts of the facility and other variables such as instantaneous fuel consumption, torque, engine speed and throttle position together with the need to control the plant justify a change from the traditional methods of transmitting signals in separate lines, for the application data exchange network. The authors' assumption of the organization was

based on data flow using the protocol CAN (Controller Area Network) with the Matlab Simulink and RTW. The article contains a description in the context of implementing the network-specific features of CAN in particular regarding the mechanisms, such as arbitration on the bus, the method of initiation, or to provide sufficient transmission capacity. The presented graphs and diagrams illustrate the proposed and implemented solutions and the results obtained from the surveys measured temperatures for the warm-up and cooling of the engine.

In recent years there has been a constantly increasing popularity developed by engineers at Bosch CAN protocol (Controller Area Network). The area of application of CAN-based networks is very wide, ranging from a significant presence in industrial automation, as the data layer in the CAN Open or Device Net, to apply in automobiles where CAN is the basic communication system. The primary source of information on CAN network is contained in the specifications of the CAN Specification 2.0 Part A and CAN Specification 2.0 Part B. Following a very positive endorsement by the users and their wide dissemination, the records of the above specifications contained in ISO 11898-1 and expanded the description layer physical standards ISO 11898-2 and ISO 11898-3. Rich material on aspects of the protocol in the car is also now available in Polish and foreign literature [1-8].

Basic features of the network included in the above-mentioned documents are:

- Network-type organization multimaster,
- Relatively high-speed connections up to 1Mbit/s,
- Network flexibility, because of the possibility of reconfiguring nodes,
- Clear and efficient mechanism to temporarily arbitration.

Among the reasons for which the CAN finished in a strong position compared to other means of data transmission, particular attention should be paid to the fact that for many applications, it provides an excellent compromise between the simplest ways of transmission such as RS 232, and much more complex ways, such as Ethernet. Data transmission in the CAN network is not dedicated to the principle of sending large data packets such as “bulk transfer”. Adopted capacity data frame is up to 8 bytes [8], which in extreme cases when reporting the value of the double-precision floating point format means the use of one frame for the transfer of one variable. In the automotive control systems a more important role, is having, the possibility of repeated and rapid delivery of small portions of information to which this order is perfectly predisposed for CAN. From a purely technical point of view, a widely accepted solution to the physical layer allows direct connection to the bus transmission lines, which eliminates the need for devices like switches or hubs. An additional very favourable circumstance for the widespread use of CAN is the fact that all major manufacturers of electronic components now equip their products in the CAN interface performing a task in a manner in which hardware data layers within a single IC.

## 2. Selecting the concept of data exchange system

Many conflicting criteria should be taken into account when facing the choice of transmitting signals. The most important characteristics required for the position are described in this article:

- resistance to the transport system arising in the immediate vicinity of the disturbance caused by electromagnetic brake work,
- ability to work with the software environment enabling the so-called engineering science, fast prototyping (rapid prototyping) allows for the shortening of the research cycle time by eliminating the gaps needed to adjust the position of the various phases of the experiment,
- flexible control of data flow can be understood as the possibility of modifying the algorithm in constant communication hardware,
- separation of the physical location of the controlled object and the main registering and computing units because of the onerous conditions of measurement (noise),
- ensuring a high level of data rates,
- the possibility of flexible hardware reconfiguration, modification and expansion of the position,

- compliance with the applicable general standards of information transmission,
- able to work in real time implies the need to ensure a sufficient degree of time determinism in the communication system,
- installation costs as low as possible.

In the context of these circumstances, the application of the classical method of transmitting signals based on the individual lines connected to the inputs and outputs, measuring cards would experience some problems. The multiplicity and diversity of data points and the actuator is related in these solutions with difficult access to the test object. A no less significant problem in remote location set up recording equipment and transducers is to extend the connecting analog lines, which in turn have an influence of the increase disturbances and the quality of transmitted signals. The use of individual registering devices and implementing device drivers that communicate through a digital network eliminates some of these problems. An another extremely important feature of this solution is access to diverse information (frequency, voltage, the current, resistance) in a uniform manner for the transmission of digital data, which was why it was decided to use the CAN network (high speed). Control and monitoring of the facility was based on the Matlab Simulink environment RTW. The final versions of the communication system adopted by the authors are shown in Fig. 1.

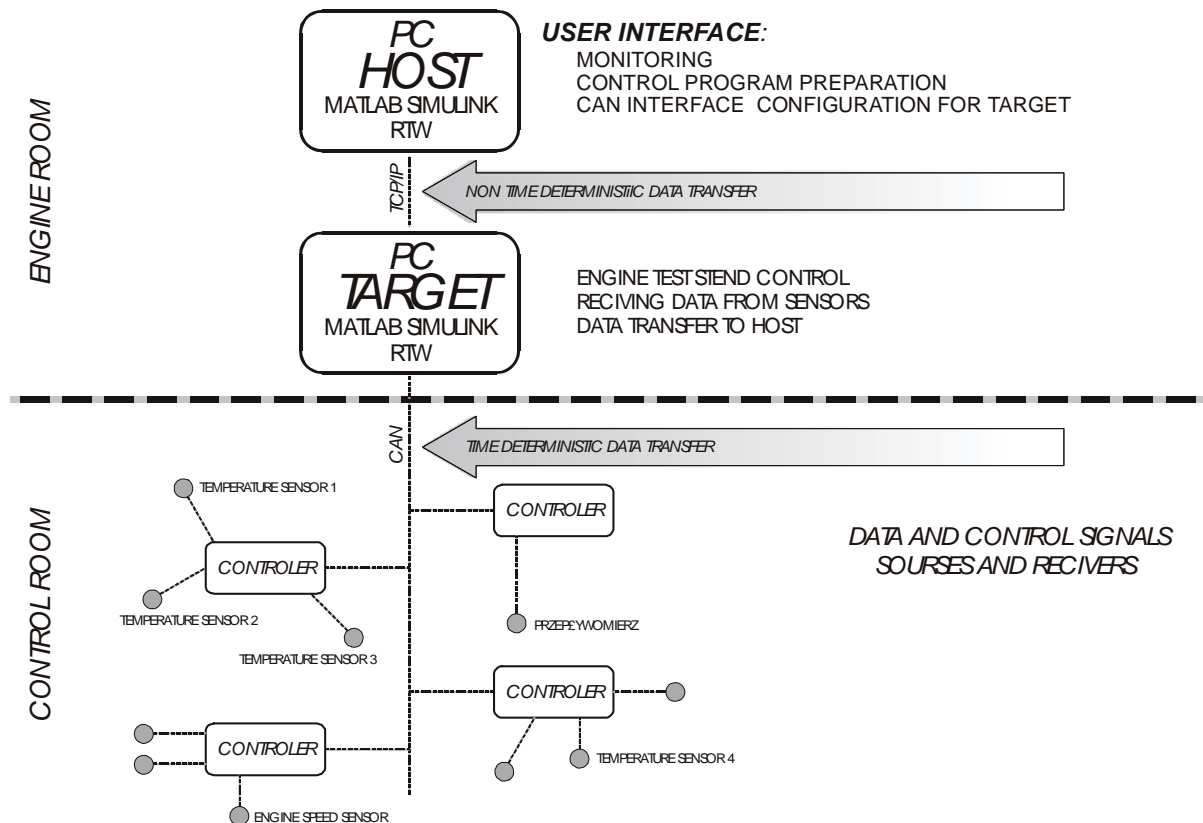


Fig. 1. Diagram of control and data acquisition as a test car engine cooling system

### 3. Description of the implementation of a communication system

While the data layer bus based on CAN protocol is clearly defined, users and designers of the network have complete freedom in the other layers of the OSI model.

Given the assumptions made, the communication system has been designed taking into account the need to ensure a high degree of determinism in time, and high throughput. The appropriate way for the CAN network transmission is called initialization. The triggering event, which means sending a data frame following a fact occurring, such as receiving a frame type of request data

(request to send data). This way of regulating the network traffic is unfortunately at odds with the requirement to achieve the highest degree of determinism in time. An alternative to using a triggering event is a triggering at certain moments of time called time-triggering. An example of such an organization of data flow can be TTCAN network (time triggered CAN), but has not spread as equally as described in the standard CAN Specification 2.0. The need for additional buses on the information to synchronize transmission nodes, and “hardening” time-sharing available information set portion results in most cases and reduces the network throughput. Used as a way of initiation transmission combines the two mentioned options, i.e., event triggered and time triggered.

Simplified diagram of the location of the temporary data on the bus shown in Fig. 2 (sequence data in a CAN network on the bench).

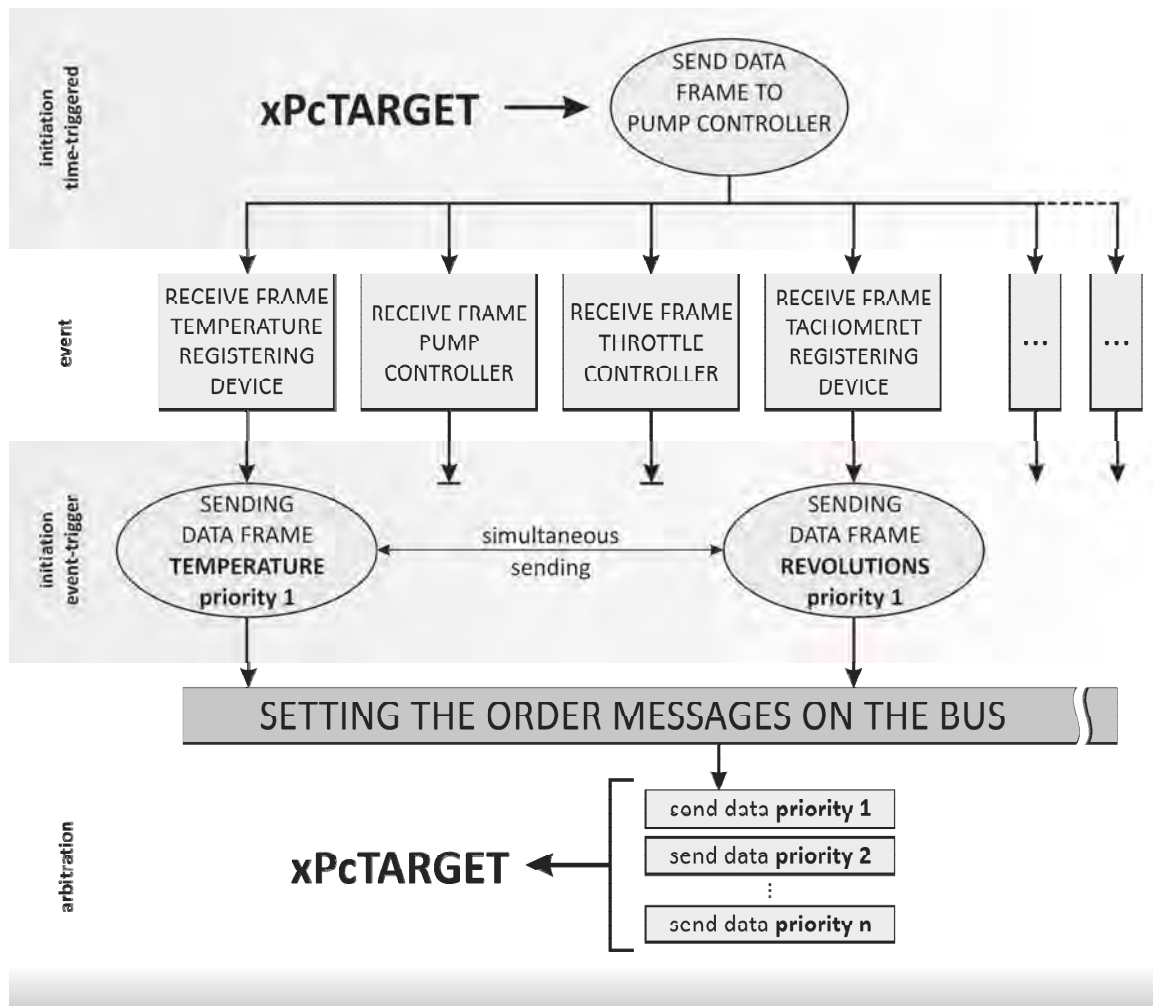


Fig. 2. The sequence data in the CAN network as a test car engine cooling system

Features a fully triggered time forming part of the Environment RTWtarget Matlab driver, which sends the information to the frame of the driver pump (frame ID 001) at regular intervals in each new cycle starting transmission on the bus. Determination of accurate timing is not a feature of the network itself but rather the control test object in the form of realtime XPC Target. Later the release cycle is done on a triggering event, which features a fully initiating event which appears on the bus Data Frame 001 Further control signals are sent thus measuring the bus, as a reaction to the withdrawal of the frame by the other drivers. The sequence of undistorted transmission of each of them is determined by arbitration proper CAN protocol. Control cycle time achieved in the system is up to 0.01 s. In order to further increase network capacity, individual devices connected to the nodes are designed and constructed following the principle of “maximum fill the frame”. Given

the fact that the actual amount of time needed to transfer data in relation to the total time of broadcasting is, in extreme cases up to 10% [9], in some cases the values of several signals were placed in individual boxes. One example is temperature recorders, which combine measurements of 16-bit for one frame in the form 4x 16bit.

#### 4. Measuring points on the engine dyno type M111920

Measurements of the concept of the design of the cooling were performed on a dynamometer, a spark-ignition engine with a swept volume of 1.8 dm<sup>3</sup> electromagnetic driving brake.

Holes made in the cylinder liners extending to a depth of 2 mm under the sliding sleeve for the introduction of thermocouples to measure the temperature of the metal. Method of attachment of thermocouples to measure the temperature of the cylinder liner and the coolant around the bush is shown in Fig. 3.

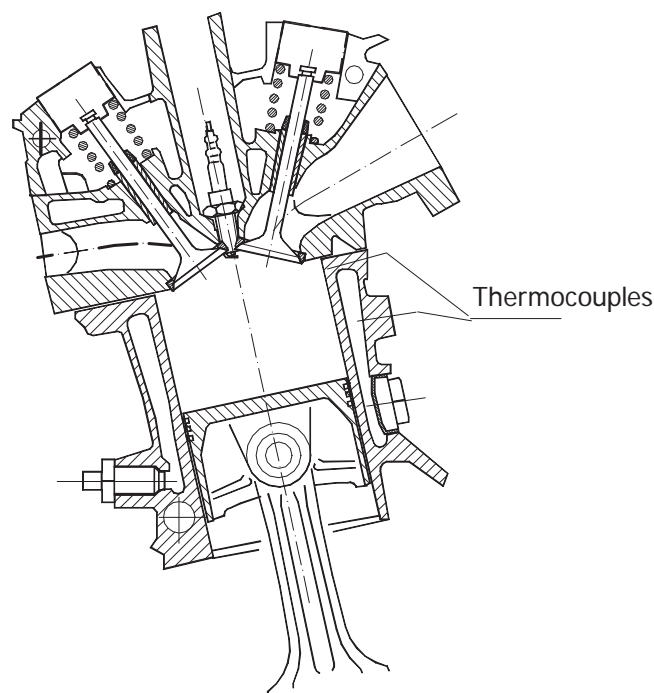


Fig. 3. Location thermocouple recording the temperature of the cylinder liner coats and space cooling liquid engine block

All items on the fast registration of temperatures and coolant flow are shown in Fig. 4.

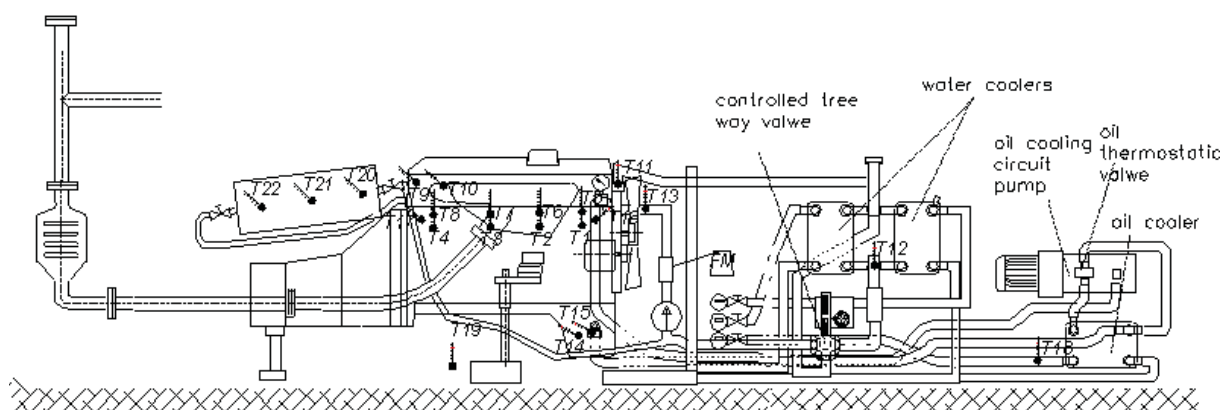


Fig. 4. Points of temperature measurement and flow in an experimental cooling system on the engine dyno: T1-T22 – temperature measurement points, FM – coolant flow



During the tests, recorded temperatures than those mentioned above, coolant flow, engine speed, engine torque, gasoline injection timing.

System of registration of the measured parameters of Fig. 5 shows.

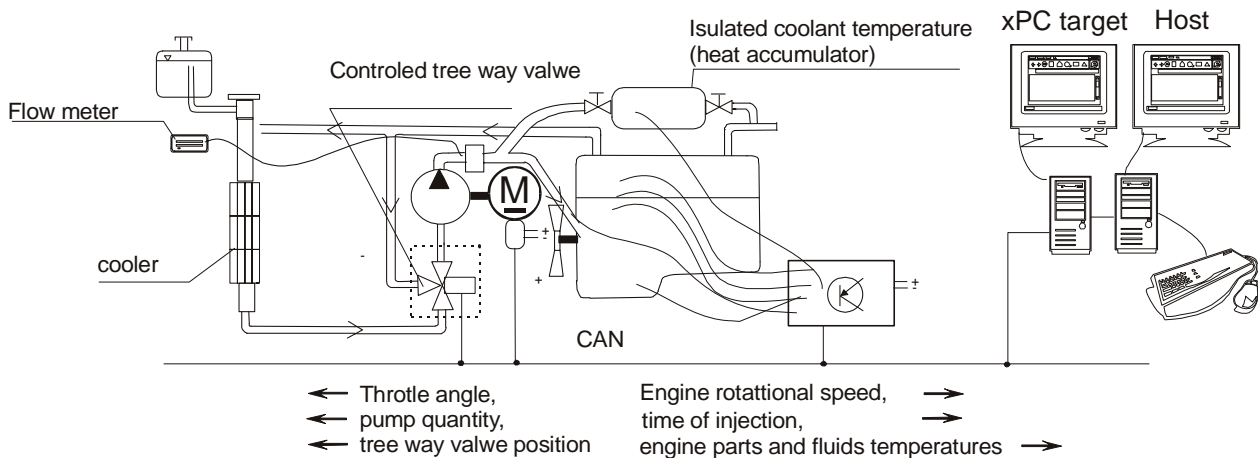


Fig. 5. Schematics of the developed test stand

11 thermocouples were installed to measure temperature and fluid elements inside the engine. Temperature measuring points have been selected to represent the state variables in the equations of state built a mathematical model of the engine cooling system. 6 further thermocouples were placed on the circuits of the cooling liquid and oil, 2 in the exhaust manifold and 9 in the resistive circuits, transducers and liquid oil. The flow of coolant entering the engine is measured by an ultrasonic flowmeter. There were also other methods which are normally used in laboratories for determining the basic parameters such as an engine torque, rotational speed, fuel consumption, exhaust gas composition, and others.

## 5. Conclusion

The obtained results confirm the position of usefulness and the ease of implementation of the CAN to the individual applications on complex objects working in real time and the importance of proper organization of information flow in the network (at a given level of temporal determinism) to increase its capacity for information.

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