Using the CAN Protocol for Climate Control System in Automotive Indoor Monitoring

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Abstract-This paper presents the design and implementation of CAN (Controller Area Network) nodes as part of the Climate Control Systems. The proposed Climate Control System is developed as following of the main characteristics of the CAN protocol in data transfer and of the new generation smart transducers key characteristics in order to rich the requirements concerning the indoor air quality (IAQ) in cars park.

I. Introduction

It is important to provide a good controlled climate in the vehicles, because many people must spend a lot of time every day inside. This optimizes the performance for driver and gives comfort for all car occupants. Consequently, it is necessary to use on-board monitoring for counteract the problems caused by decreasing of air quality. As parameter that characterizes the air quality can be mentioned the temperature, the humidity and the concentration of pollution gases such as CO, CO2 or smoke.

The design of a such system depends of several measured and/or controlled parameters as vehicle-inside air temperature, air blowing speed on exposed skin, vehicle-inside sunlight radiation and thermal radiation level, humidity of the air, activity of the person, clothing worn by the persons[1, 2, 3].

IAQ monitoring is a process in which air inside a structure is regularly tested to gather information about its quality. Test results are used to manage a climate control system and to take other steps which may be necessary to protect health. There are a range of environments in which air quality may be monitored. One goal of indoor air quality monitoring is to ensure that the air inside a structure is safe to breathe. Indoor air quality monitoring is especially important when gases are present. Some gases can cause suffocation by forcing oxygen, and often people are not aware that they are not getting enough oxygen until it is too late. In other cases, a gas may be hazardous because it is toxic. Indoor air quality monitoring is very important for safety [4].

Air quality can be expressed by the concentration of several pollutants such as carbon monoxide (CO), sulphur dioxide, nitrogen dioxide, and ozone. The threshold values specified by the European Environment Agency [5] for these pollutants are 10, 350, 40, and $120\mu g/m^3$, respectively. Pollution also needs to be considered inside our homes, offices, and schools. Some of these pollutants can be created by indoor activities such as smoking and cooking. Generally, in industrialized countries, the population spends about 80%–90% of time inside buildings and is therefore exposed to harmful indoor pollutants. Indoor air quality is generally assessed by separately measuring CO, temperature, and humidity [6].

In the present work are included elements related the CAN protocol, the CAN based architecture for air quality monitoring, elements of sensing and experimental results.

II. CAN Protocol

The Controller Area Network [7] is a serial communication protocol designed for communication between microcontrollers, which supports distributed real-time control with a very high level of security. In an automotive environment it is used to exchange information between onboard Electronic Control Units such as the Engine Management System, transmission, instrument packs, and body electronics. CAN makes the connection between nodes using two wires, twisted pair cable. As first advantage of using CAN in automotive industry, presented in Figure 1, is the great diminution of the electrical connections weigh because CAN replaces a lot of wires used for this purpose.
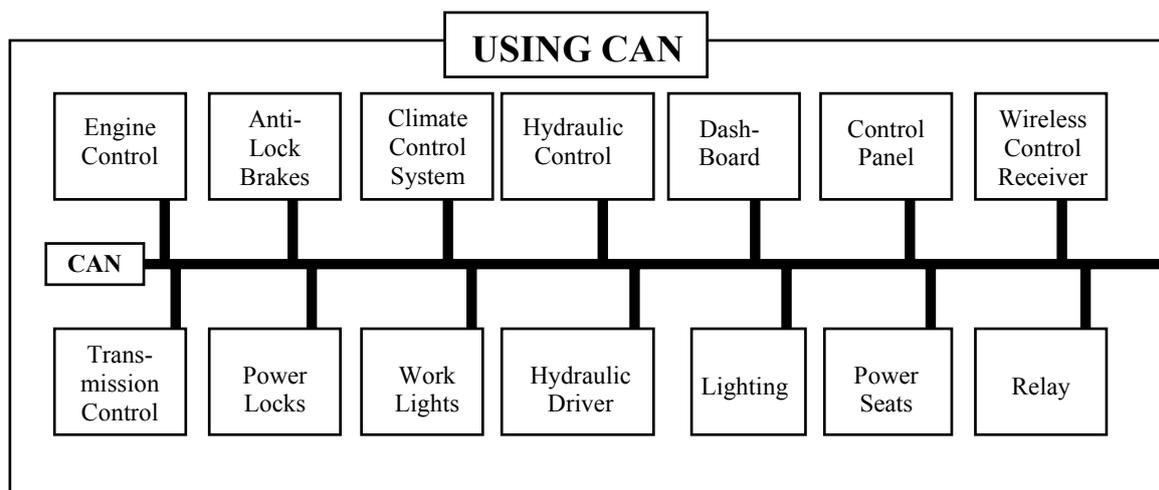

Figure 1. Automotive components connected with CAN.

CAN has some important proprieties like prioritization of messages, guarantee of latency times, configuration flexibility, multicast reception with time synchronization, system wide data consistency, multimaster, error detecting and signalling, automatic retransmission of corrupted messages as soon as the bus is idle again, distinction between temporary errors and permanent failures of nodes and autonomous switching off of detected nodes [7, 8].

Another key feature of CAN protocol is the allowing of the direct connections of smart transducers (sensors and actuators) in systems dedicated to real-time control applications. These transducers have new important characteristics as self calibration, computation, communication, multisensing, regulated in the IEEE 1451 Interface Standards. This family of standards describes a set of open, common, network-independent communication interfaces for connecting the smart transducers to microprocessors, instrumentation systems, and control networks. The goal of IEEE1 1451 is to allow the access of transducer data through a common set of interfaces when the transducers are connected to systems or networks via a wired way as CAN [9].

All presented above features of CAN architecture will be used for developing of the proposed Climate Control System.

III. Distributed air quality monitoring system based on CAN architecture

There are many requirements for an automatic and well regulated air-conditioning system in automotive. Sensor systems are becoming more complex and the need for high quality and effective cost sensors is increasing. The control of the air-conditioning must require only the smallest attention from the driver. Effective air-conditioning helps the driver to keep an optimal condition in the most delicate situations and minimizes the stress on the passengers. Longer trips tend to be hard for both drivers and passengers, but a well functioning air-conditioning system reduces some of the discomfort [10].

An example of a block diagram for the acquisition node based on CAN is presented in Figure 2. Multiple devices can be simply connected to the bus and there are no logical limits to the number of devices that can be connected, excepting the bus delay time and electrical load.
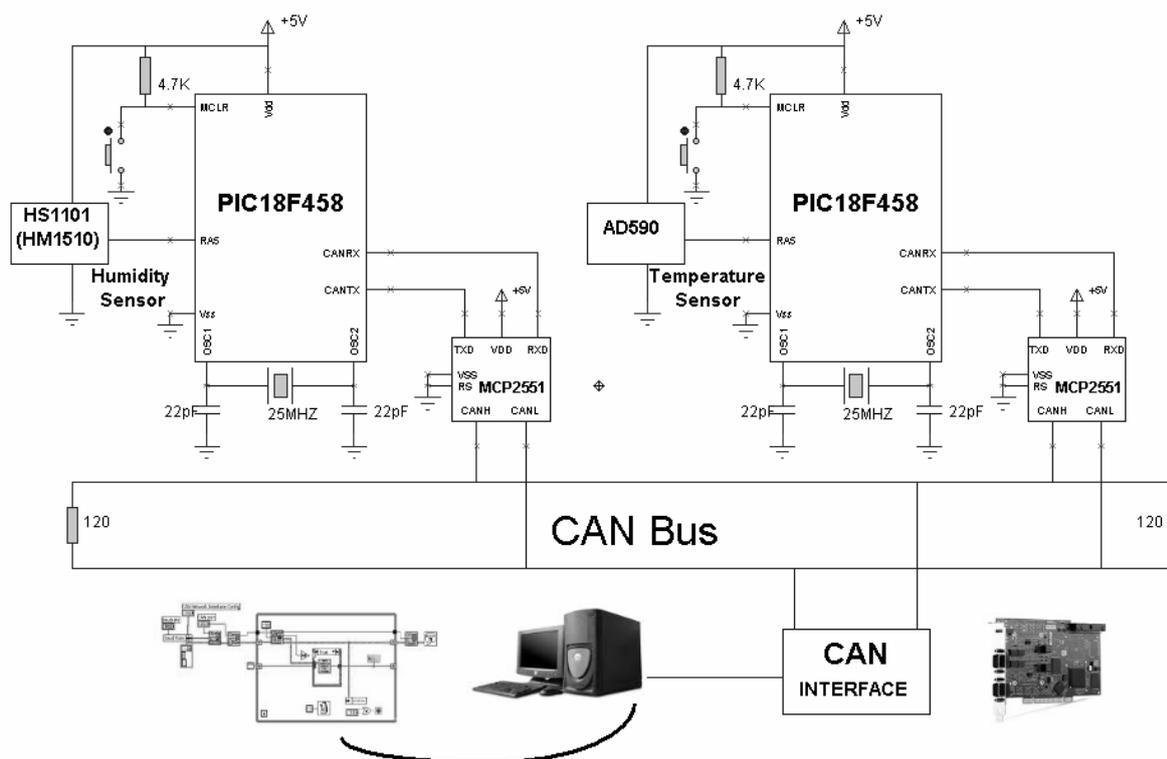
Figure 2. Block diagram for the acquisition node.

Every Data Acquisition Node consists of a PIC18F458 microcontroller with a built-in CAN module and an MPC2551 transceiver chip. Sensors that can be used in this kind of system are Temperature Sensor (NTC – Negative Temperature Coefficient, PTC – Positive Temperature Coefficient), Sun Load Sensor (photovoltaic and solar cells), Pressure Sensor (capacitive, strain gauge, piezoelectric), Position Sensor (linear and rotary potentiometer), Speed Sensor (Hall effect and inductive), Humidity Sensors (capacitive), Pollution Sensors (MOS – Metal Oxide Semiconductor). Typical actuators used to achieve the desired action are Solenoids (relays, coolant valves), Motors (permanent magnet), and Stepper motors (DC permanent magnet, variable reluctance, and hybrid) [11 – 16].

A. Humidity sensing

For humidity testing we used an HS 1101 sensor [17]. Based on a unique capacitive cell, these relative humidity sensors are made for high volume, cost sensitive applications such as office automation, automotive cabin air control and industrial process control systems. Typical characteristics for output voltage at Vcc 5V and 25°C is presented in Figure 3.
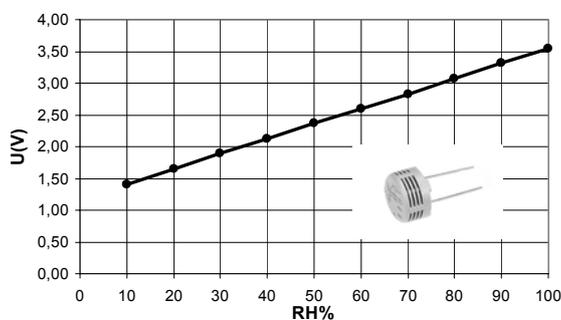

Figure 3. Output voltage for HS1101 sensor.

The main features of the HS 1101 sensor [17] are interchangeability, instantaneous desaturation after long periods in saturation phase, compatible with automatized assembly processes, high reliability and long term stability Suitable for linear voltage or frequency output circuitry, fast response time. Internal bloc diagram for

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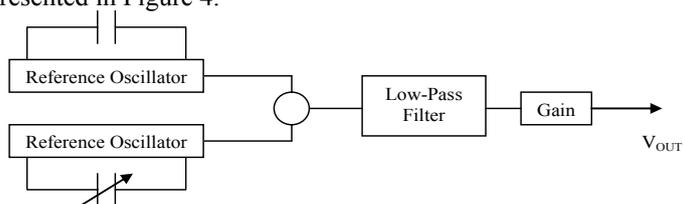this humidity sensor is presented in Figure 4.

Figure 4. Block diagram for HS1101 sensor.

The output voltage for 5-99% RH is given by the relation: $V_{OUT} = V_{CC} * (0,00474 * RH\% + 0,2354)$.

B. Temperature measurement

The AD590 is a two-terminal integrated circuit temperature transducer that produces an output current proportional to absolute temperature. Figure 5 shows the typical voltage-current characteristic of the circuit at 25°C and the temperature extremes [18].
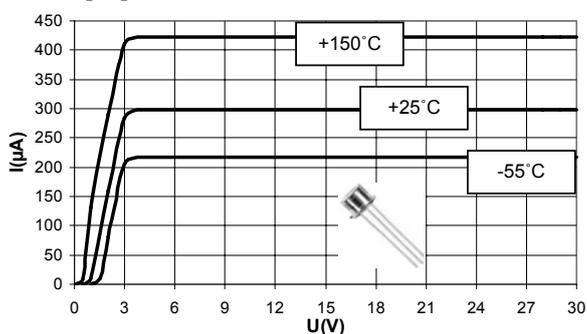

Figure 5. Voltage-Current characteristic for AD590 sensor.

For AD590 the proportional to absolute temperature voltage is converted to a proportional to absolute temperature current by low temperature coefficient thin-film resistors. The total current of the device is then forced to be a multiple of this proportional to absolute temperature current.

IV. Results and discussions

A. Communication testing

For communication testing we used a labview application Figure 6, which consists on open and configure the CAN network interface, read and display part of the contents of the read buffer and the closing network interface part with error message, if it appears. The baud rate is set to 125kbits/second and the Read Queue is set to 150 which allow reading up to 150 received frames.
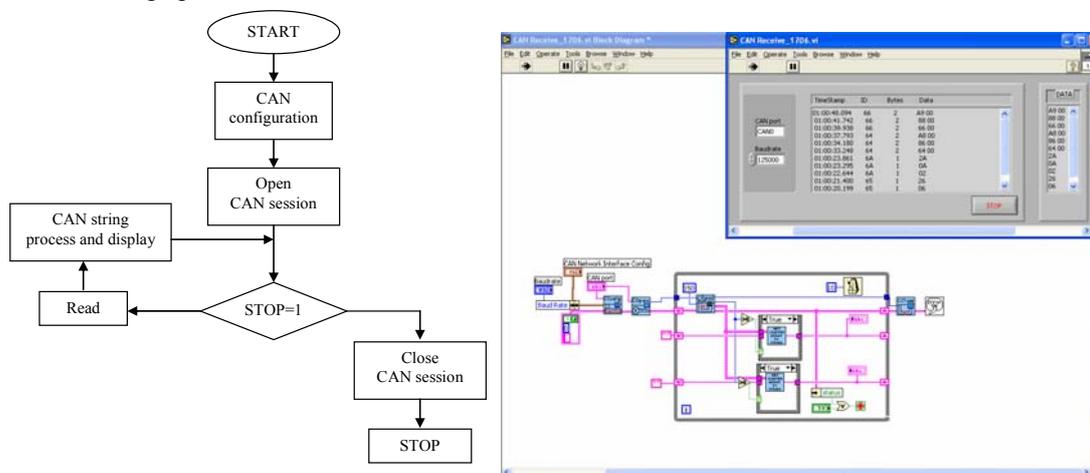

Figure 6. Testing CAN communication method.

Configuration was made by CALL DLL function which is internal implementation of CAN VI. That permits to call a DLL application directly without using a cod interface node. Net Cluster Array was used for receive data from Network Interface. The timestamp field displays the actual time when CAN message arrive at CAN port. The arbitration ID represents the ID of CAN's message. IsRemote field shows if the received message is a Data or Remote message. Data Length displays how many data bytes came in the CAN message and Data array shows the data bytes in the CAN message.

B. Sensors signal characteristic on CAN Bus
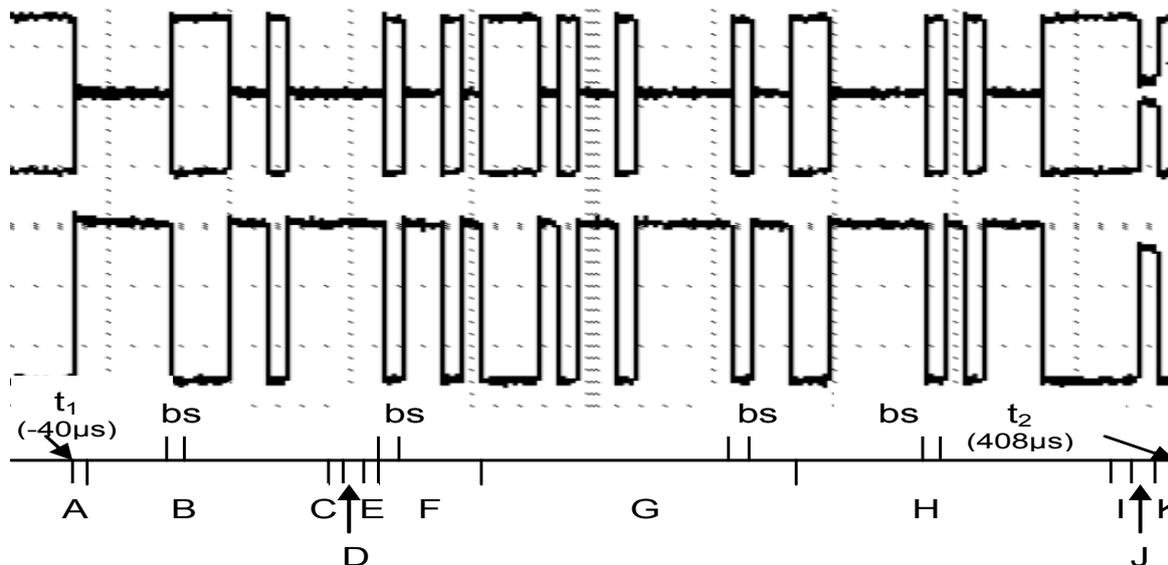

Figure 7. Signal on CAN Bus.

In Figure 7 is presented the signal form that appears on CAN Bus where:
A – 1 dominant bit corresponding to the of Start of Frame section;
B – 11 bits that, accordingly with CAN Specification 2.0A, uniquely identifies each communication object, in our case is hexadecimal representation for ID 64 (000 0110 0100);
C – 1 dominant bit which distinguishes data and remote frame types;
D – 1 dominant which corresponds to the identification bit of the plot;
E – 1 dominant bit reserved r_0;
F – 4 bits corresponding to Data Length Code, in this case DLC is 2 (0010);
G – 16 bits are used for transferring information E901, which in hexadecimal is 1001 1000 0000 0001;
H – 15 bit corresponding to Cyclic Redundancy Code used by receivers to check the integrity of incoming frames;
I – 1 recessive bit corresponding to Cyclic Redundancy Code Delimiter;
J – 1 dominant bit corresponding to Acknowledge Field;
K – 1 recessive bit which corresponds to Confirmation Filed;
bs – Bit Stuffing.

Having Baud Rate at 125kbit/second we can obtain the time bit, which is t_{bit}=8µs. The total time of the frame is given by the relation t_2-t_1=408µs-(-40µs) =448µs which corresponds to 56 bits. From this 56 bits, 52 bits are dedicated for transfer of data E901, with ID 64 and data length DLC=2. The others bits correspond to that 4 bit staffing.

IV. Conclusions

The digital signals associated with CAN transactions were analyzed using a virtual CAN analyzer associated with the implemented network. The CAN protocol with its proprieties must be used at high speed for data processing in case of Climate Control System in real time. The benefits of the proposed Climate Control System are decreasing of the cooling load by a more adaptive and more complex automatic control, monitoring of IAQ, detection of the human being or pets left in the parked cars for their safety, full use of the air recirculation system facilities for reduction of the fuel consumption or for avoiding occasionally disturbance of IAQ. As a result of networking in automotive based on CAN protocol, the proposed system for indoor air monitoring allows to

command it equally from a central point or distributed points. Based on this architecture it results an increasing of the functionality and a freedom in the diagnostic processes.

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