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CAN PROTOCOL: A LABORATORY PROTOTYPE FOR FIELDBUS APPLICATIONS

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Abstract − An integrated solution based on CAN protocol, for industrial measurements and control, is presented. Main characteristics of CAN protocol are underlined in terms of OSI model taking particular attention to hardware implementation, messages types, collision resolution mechanisms and timing synchronization. The paper also includes references to another high level industrial protocols that use the physical and logical data layers of CAN protocol. Experimental results based on a developed prototype applied to a level control loop system and main protocol characteristics are analyzed.

Keywords: CAN, OSI protocol layers, fieldbus networks

1. INTRODUCTION

By 1960 the analog electronic instrumentation, using 4-20 mA, had a fast spread in the field, and soon replaced the pneumatic 3-15 PSI standard. This was also the start time of computers usage for measurement and control. At that time, the central computer receives all analog 4-20 mA signals, converts those analog signals to digital, processes the information, display values and graphics, makes reports and outputs signals to the actuators (control valves and motors). Smart instrumentation appeared by 1980. It added many facilities to the instruments, mainly in what concerns self-diagnostics, alarms and tagging.

This paper dedicates particular attention to control area network (CAN) protocol, its main characteristics and applications.

2. CAN PROTOCOL

CAN appears as a solution to automotive industry [1] and its main objective was to get a robust digital transmission solution to interconnect a large number of automobile smart devices. This protocol was optimized for systems that need to transmit and receive relatively small amounts of data with real time requirements. The main characteristic of CAN protocol are summarized in Table 1.

Table 1. Main characteristics of CAN protocol

Bus Access **Bus Allocation**	**deterministic** **central or distributed** **random**
Addressing	message address
Media	Single wire, UTP optical fibre
Topology	bus - tree
Hierarchy	Multi -master
Bandwidth	Bitrate (kBps)

Nowadays, CAN based protocols extend their applications' domain in multiple areas. Two well-known protocols derived for CAN are CANopen [2] and DeviceNet [3].

CANopen is a CAN-based higher-layer protocol that is frequently applied in embedded control systems. The set of CANopen specifications comprises the OSI application layer [4] and communication profile as well as application, using the same set of physical and logical data layers of CAN protocol. These networks types are used in a very broad range of application fields such as machine control, medical devices, off-road and rail vehicles, maritime electronics, building automation and power generation. The main advantages of CANopen are its plug and play capabilities, interoperability and interchangeability. DeviceNet is mainly used in factory automation as a communication network between industrial I/O devices and controllers DeviceNet supports multiple communication hierarchies, message prioritization that is one of the main characteristics of CAN protocol and other additional performances that are required by industrial fieldbus [5] networks such as robustness, error recovery mechanisms, redundancy and low-cost implementation.

2.1 OSI model

The international standards organization (ISO) defined the open system interconnection (OSI) model that includes seven layers, namely: application, presentation, session, transport, network, data link and physical layer. These layers that include the transmission rules of any protocol can be used with various bus network topologies.

Fig. 1 represents on the left side the OSI model layers and on the right side the main tasks of the first two layers used by CAN protocol. It is important to underline that CAN protocol does not specify some parts of the physical layer, namely cabling and connectors.

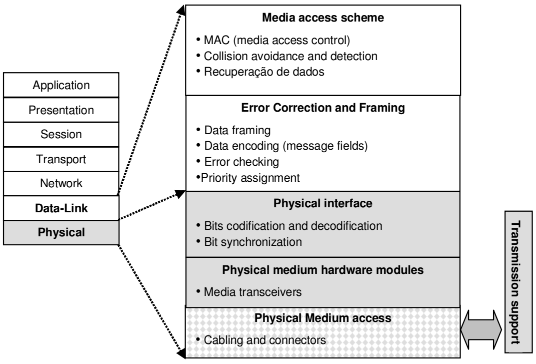

Fig. 1. Summary of the main tasks associated with CAN's protocol layers.

2.1. Frame types

CAN protocol define four different frame types: data frame, remote frame, error frame and overload frame. Data frame are mainly used to exchange measured variables and control data between network nodes

Remote frames are used when one node request data. In this case a recessive remote transmission (RTR) bit without any data is sent. The error frame signalizes transmission errors. In each network node there are several counters that are used to count temporary and permanent node failures. If the number of errors exceeds the predefined limits, the faulty node is removed from the network in order to preserve network operation. An overload frame is used when a network node is too busy. In this case the others networks nodes are requested to delay the start of the next transmission for a short period of time. This frame is identical to an active error frame, however overload frames does not increase the error counters and does not causes frame's retransmission.

2.2 Collision resolution mechanism

CAN bus access is performed in a multimaster mode, that means the bus access in not managed by a master node but any node in the network can act as a master depending on message priority level. Messages are broadcasted through the network and each node determines if that messages should be received or not, accepting or ignoring it, respectively. The protocol does not require addressing mechanisms that means each message packet does not require source and destination fields. However, each CAN packet has an identifier field defining message type and priority. Bus access for maximum priority messages is performed within a maximum predefined time delay. When several nodes start transmission of a frame simultaneously, a bus conflict is resolved by a non-destructive contention-based arbitration without any destructive effects on high priority messages.

3. SYSTEM DESCRIPTION

The CAN protocol implementation project was done at the Instrumentation and Measurement Laboratory at ESTSetúbal using an assembly that simulates an industrial process. The experimental set-up, depicted in Fig. 2, contains a closed tank with water and pressurized air and an open tank that delivers water to the outside. The target is to control the pressure in the pressurized tank and the water level in the open tank.

The water level inside the pressurized tank is measured using two pressure transmitters with analogue outputs, one installed on the top of the container and another at the bottom (P3 and P2, respectively). To control the pressure inside the tank the input water flow is adjusted considering that there is water consumption through valve V3, by commanding the motor (B1) with a speed controller (Sv). This tank feeds the open tank through a valve (V7) that is opened or closed depending on the water levels (inside the pressurised tank and in the open tank). To indicate the water level in the open tank another pressure transmitter (P2) also having an analogue output is used. The water is delivered to the output by acting valves V2 and V4.

Fig. 2. Experimental set-up of level control system.

Thus there are three process variables and four control variables: the pressure transmitters (P1, P2 and P3) and the frequency of the motor speed control, the valve V7 and the ON/OFF action of V2 and V4 valves. When there is water flowing to the output, the water level of the open tank (P2) must be put back by setting valve V7 open during a time interval and the pressure in the pressurised tank (P1 and P3) must be kept at the setpoint. By acting ON/OFF V2 and V4 the system can be also controlled.

As depicted in Fig. 3 it was decided due to the location of the devices to implement the CAN network with four nodes. Each node includes besides the fieldbus devices a CAN module. Each module includes one microcontroller PIC18F2580 used as the CAN controller [6], one MPC2551 [7] used as a high-speed transceiver, the bus and any conditioning circuit needed to interface the microcontroller.

The exchange of information between the nodes is presented in Table 2.

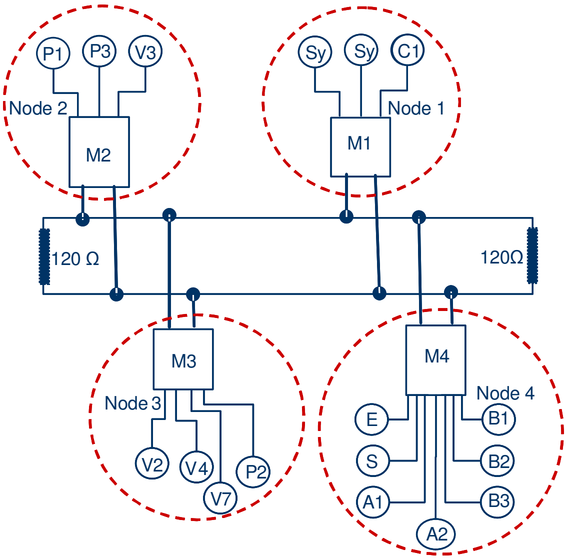

Fig. 3. CAN network and bus terminating resistors.

Table 2. Signals between CAN nodes.

Transmitter		Listener	
Node	Function	Node	Function
4	System Starts (S) if C_1=0	1	S_Y ON
		2	Close V_3 if $(P_1\text{-}P_3) \leq$ max.
		3	Close V_2 if $P_2 \leq$ max.
	Emergency (E)	1	S_Y OFF
		2	Open V_3
		3	Open V_2
	Manual V_2 (B_1)	3	Open/close V_2
	Manual de V_3 (B_2)	2	Open/close V_3
	Manual V_7 (B_3)	3	Open/close V_7
1	Input water flow (C_1)	4	Starts if C_1=0
		2	Open V_3 if flow $\geq$ max.
2	Pression (P1, P3)	1	Commands speed (B1)
		2	Close V_3 if $(P_1\text{-}P_3) \leq$ min.
		2	Open V_3 if $(P_1\text{-}P_3) \geq$ max.
		4	Alarm A_1 if $(P_1\text{-}P_3) >>$ max.
		4	Alarm A_2 if $(P_1\text{-}P_3) <<$ min.
		3	commands V7
3	Pression (P2)	3	Open/close V_2
		3	Open/close V_4
		4	Alarm A_3 if $P_2 >>$ max.
		4	Alarm A_4 if $P_2 <<$ min.

4. EXPERIMENTAL RESULTS

In order to analyze CAN bus data transmission, namely those characteristics that assure robustness to the protocol, several tests in a simplified version of the fieldbus network with only two nodes (Fig. 4) have been conducted.

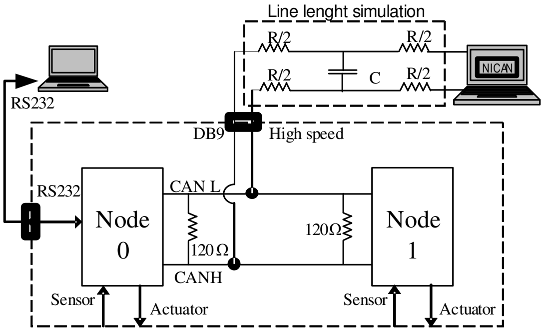

Fig. 4. Diagram of the experimental setup.

Tests were performed transmitting a frame introduced into the bus by a CAN PC board [8, 9] using a developed LabVIEW application. The simulated signal, represented in Fig. 5, is a command to activate an actuator.

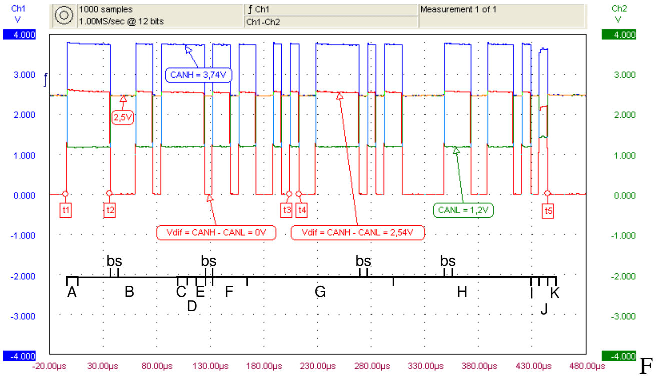

Fig. 5. Signal generated by the LabVIEW.

In order to analyze the influence of cable length in the CAN bit stream with a data rate of 125 Mbit/s it was used an artificial line with concentrate parameters were made as presented in Fig. 4. Fig. 6 represents the data stream when a cable length of 498 m is used. The parameters calculated for

498 m are: R = 17.73 Ω and C = 27.39 nF. The signals obtained for the previous situation are depicted in Fig. 6.

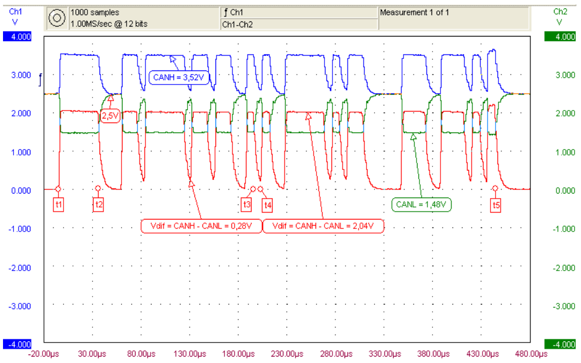

Fig. 6. Message in a 498 m bus lenght.

The high-speed CAN specifications require 120 Ω terminal resistances. Fig.7 shows a sequence of error frames. After a specific number of errors transmitted (256) the internal counter disconnects the bus.

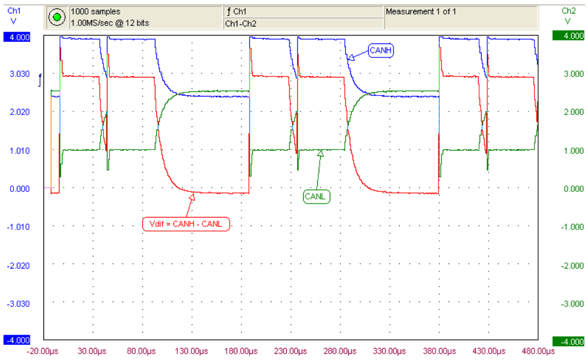

Fig. 7. Bus signals when one terminal resistor is missing.

Fig. 8 represents the signals obtained when a 20 kHz with 5 Vpp is superimposed with the message signal. As both lines experience the same interference the differential voltage remains almost constant and CAN communication remains successful.

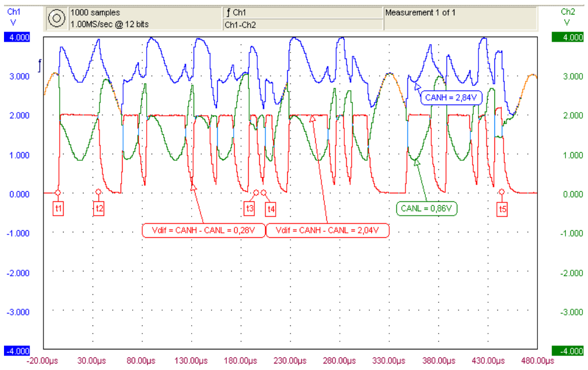

Fig. 8. Signals obtained when a 20 kHz/5Vpp noise signal is superimposed to CAN bit stream.

5. CONCLUSIONS

The experimental results confirm the excellent performance and robustness of the CAN protocol when used in industrial applications. The main advantages can be summarized as: reduced cabling (by the use of several instruments over the same bus), error detection capabilities, high immunity to external noise signals (present in industrial processes), robustness, capability to solve bus access collisions without any retransmission requirements, distributed control and hot-swapability. As the frames are short, when compared with other fieldbus solutions, the processing time associated is also small. This means an acceptable transmitting rate for several applications in the device level of an industrial process, where the information changed between devices is very small but requires a "real-time" capability.

The experimental tests done with the developed prototype validate the expected theoretical results of CAN communication, and its reliability to external transmitting conditions in industrial environments.

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