Development of CAN based Automatic Fire Detection System

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Abstract: It is general to use the control network in control systems in order to reduce the complexity of the related wiring harnesses and to improve the system flexibility. CAN becomes one of the most popular network protocols because of its low price, multiple sources, high performance and reliability. This paper describes a CAN based real-time control of the fire detection system for the intelligent building system. The proposed fire detection and alarm system is stronger than the previous one against noises and communication media faults and can solve many problems such as complex cabling and increment of I/O ports by using many sensors. Furthermore, MMI can be achieved easily with the personal computer that is used for replacing the traditional monitoring system. The proposed system is implemented and the experimental results are given.

Keywords: fire detection, network, CAN, real-time control, MMI

1. INTRODUCTION

The predictive fire detection is important to reduce damage from fire. The fire detection method is traditionally carried out by a person like a building manager by using only the simple alarm system, but there is the limitation of human faculty so that it is very hard to observe the whole area continuously. The automatic fire alarm system is the fire-fighting equipment that automatically detects fire and informs to a building manager. It is very important to detect a fire and to warn the dangerous condition as fast as possible in order to minimize damage and the extension of a fire. But, there were a lot of wrong operations in the previous fire detection system. In that case, people would not believe the warning system and a great disaster can be occurred in case of the actual fire condition. So many techniques to reduce the wrong operations have been studied.

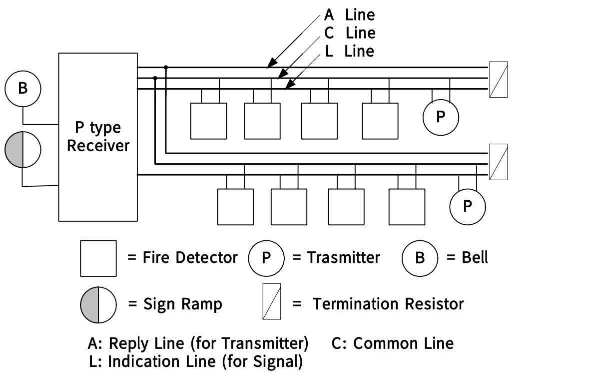
Recently, as buildings have a tendency to be larger, higher and complicated, the need of high performance detection system is growing up and a well defined MMI (Men-Machine Interface) is required basically between administrator who actually uses this facility and the detection system.

This paper proposes the CAN based automatic fire detection system. The proposed system is stronger than the previous one against noises and communication media faults and can remove many problems such as complex cabling and increment of I/O ports resulted from using many sensors. Furthermore, MMI can be achieved easily with the personal computer that is used for replacing the traditional monitoring system.

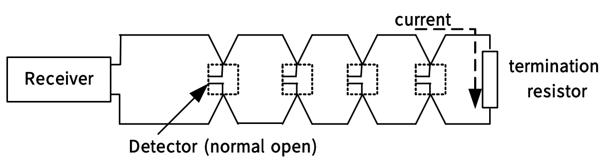
This paper is organized as follow. Section 2 introduces the conventional automatic fire detection system and the network based automatic fire detection system. Section 3 provides a general introduction to CAN and its architecture. Section 4 illustrates the message ID allocation method for reliable real-time communication. Section 5 discusses the response time analysis to satisfy the fire regulation. Section 6 evaluates the performance of the proposed system through the timing calculation and experiment. Finally, section 7 presents our conclusions and gives some directions for future study.

2. AUTOMATIC FIRE DETECTION SYSTEM

The automatic fire detection system consists of receiver, repeater, detector, transmitter and display part. Detector or transmitter delivers a fire alarm signal to the receiver, which generates alarm signal and indicates the location of the fire point, either directly or indirectly through the repeater. Fig. 1(a) shows a block diagram of the traditional P(Proprietary) type automation fire detection system. Fig .1(b) shows internal configuration.



(a)



(b)

Fig. 1 Structure of Conventional fire detection system
(a) Block Diagram (b) detecting circuit

This system that is composed of receiver and detector is watching current that is flowing through the termination resistor (10KΩ) of circuit in normal state. When the fire occurs, the current flowing in the receiver grows to a high value compare to the normal value because at least one of detectors becomes to be short. Thus, in P type system, it is hard to find the fire point despite of detecting the increment of line current because all detectors are connected in parallel on the common line even if the line current increases. This means the receiver only knows which line is in the fire place. Moreover, it is impossible to find the error even if the detector is removed or there is the leakage current by the short circuit. [1]

Fig. 2 shows the CAN based automatic fire detection system proposed in this paper. The personal computer which is the main controller of the system manages all system devices and the operating system related to the fire detection system. The detectors have CAN modules for communication and the actuator modules are used for putting out a fire and human rescue when there is a fire.

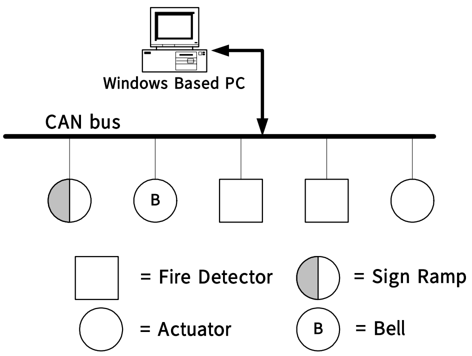


Fig.2 CAN based automatic detection system

In our system, it is very easy to find the fire point because each detector has its own identifier. It is possible to reduce the operative error for the sensors by adjustment of the sensitivity of sensors according to the environmental condition.

So, this system can find exact location of a fire and reduce a probability of detector's operative error and control alarm level in the order of urgent state. Moreover, it is easy to implement MMI by replacing the main controller to the personal computer. Because it is the network based system, remote control can be achieved easily by using a tool such as internet or cellular phone.

3. CONTROLLER AREA NETWORK

It is general to use the control network instead of the traditional peer-to-peer connection in order to exchange various data. There are a lot of protocols in control networks and the choice of the suitable protocol depends on the application area and the system requirements. Although CAN which is one of the famous control networks was developed for vehicle network, it is adopted to the factory automation area frequently because of its low price, multiple sources, high performance and already widespread acceptance. CAN has CSMA/CD+AMP(Carrier Sense Multiple Access/Collision Detection + Arbitration on Message Priority) protocol. This protocol is same as an IEEE 802.3 CSMA/CD protocol and supports physical layer and link layer of ISO/OSI 7 layers. To describe CAN protocol briefly, any node which has a message to transmit can transmit message when the bus state is idle. If several nodes simultaneously try to transmit, the highest priority node occupies bus without any delay time according to the identifier delimiter (ID) which is assigned to the messages or nodes. This method is called NBA (Non-deductive Bitwise Arbitration). Lower priority node can get the right of bus usage and retransmit the message when the bus is in idle state. CAN data format is shown as Fig.3. The CAN 2.0A defines a standard 11 bits identifier (Standard CAN) and CAN 2.0B specifies so called extended frames with a 29 bits identifier (Extended CAN). The maximum data size in CAN protocol is 8 bytes and the maximum transmission speed is 1 Mbps.[2]

SOF	Arbitration Field	Control Field	Data Field	CRC Field	ACK Field	EOF
1 Bit	12 or 32 Bit	6 Bit	0 to 8 Byte	16 Bit	2 Bit	7 Bit

Fig. 3 CAN data frame format

CAN implementation is classified as shown in Fig.4 in the point of degree of CAN integration and each integration types are described as following:

- Stand-Alone CAN Controller (Fig.4 (a)) - This type is designed to interface different CPUs allowing the software developed for one system to be reused in another system, even if the CPU is different.

- Integrated CAN Controller (Fig.4 (b)) - In the case of an on-chip CAN Controller, the CPU load on an on-chip CAN is approximately one-half of a stand-alone CAN chip.

- CAN Serial Linked I/O Device (Fig.4 (c)) - This device is a very-cost effective way to increase the I/O capability of a microcontroller based CAN node as well as to reduce the amount and complexity of wiring, but low speed.

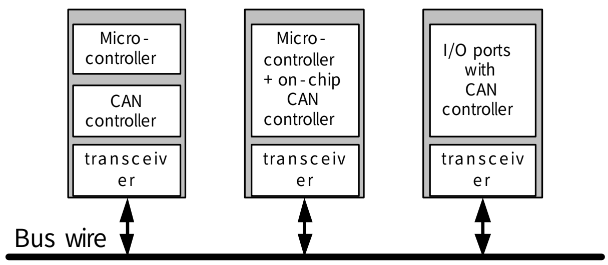


Fig. 4 CAN Controller Integration Type Classification
(a) Stand-Alone (b) Integrated (c) Serial Linked I/O

The physical CAN layer standards are based on a two-wired bus as in Fig. 5. CAN is insensitive to the electromagnetic interference because both bus lines are affected by the same magnitude which leaves the differential signal, Vdiff, unaffected. From this point of view, CAN bus system is suitable to the backbone of the fire detection system, which provides the building with the reliable service for safety.

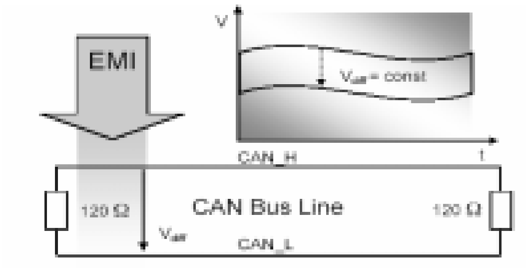


Fig. 5 CAN bus property

4. MESSAGE COMMUNICATION

4.1 Message ID allocation

CAN makes use of a wired-AND bus to connect all the nodes. When a detector has to send a message, it first calculates the message ID, which may be based on the priority of the message. The ID for each message must be unique. The message ID is defined like Fig. 6. We separate the message ID into 5 sections in order to make high quality communication.

Frame ID	Command ID	Block ID	Sensor Type ID	Unique ID

Fig.6 Structure of the message ID

The function of the message ID is summarized as following:

- Frame ID which specifies the message type as shown in Table 1.
- Command ID which specifies the fire awareness level of detector as shown in Table 2.
- Block ID which specifies the group of the fire detector and actuator.
- Sensor Type ID which specifies the sensor type of the fire detector.
- Unique ID which stands for the uniqueness of the fire detector.

Table 1. Frame ID functions

Frame ID	Name	DLC	Function
00	Extinction	0	Command for fire fighting
01	Alarm	0	Command for fire wring
10	Commend	1	Command for arbitration of node sensitivity
11	Information	1	Command for analog data of node

Table 2. Command ID functions

Frame Name	Command ID Type	Function
Extinction	0000~1111	Indicate the fire fighting
Alarm	0001	Fire awareness level 4 (Fire detected)
	0010	Fire awareness level 3
	0100	Fire awareness level 2
	1000	Fire awareness level 1
Commend	0000	Indicate the fire detector to require the analog data
	0001~1111	Adjustment of sensitivity
Information	0000	Inform the analog data

According to our message ID format, the message ID is allocated like Fig. 7 in case of the extended CAN with 29 bits ID.

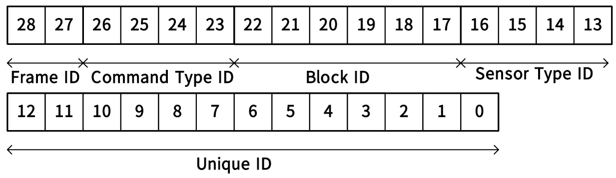


Fig.7 Message ID allocation in extended CAN

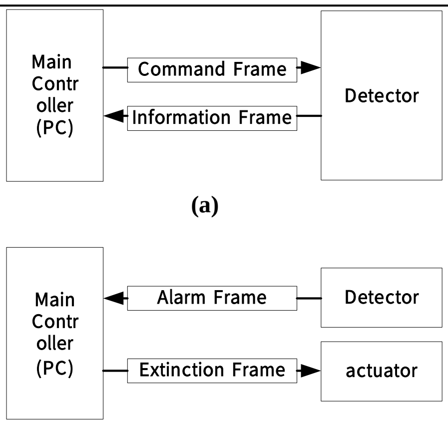
This scheme allows up to 64 different groups, 16 type sensors and 8192 fire detectors, which are sufficient for the fire detection system.

4.2 Message transmission

In the CAN protocol, the priority of message is determined by the predefined identifier as described before and the message with highest priority can transfer its message at anytime if the bus is idle. On the other hand, the message with lower priority can not transfer its data in case of collision with the higher one. In the emergency condition, the message transmission related safety must be guaranteed in spite of the lower priority. To satisfy this requirement, we make the main controller, which is usually the personal computer, poll periodically to detector and accept the urgent data with the adjustment of the sensing level automatically. At the fire accident, each detector can transmit the alarm message that has higher priority than any other messages, and then the main controller transmits the extinction frame to actuator for fire fighting. Fig. 8 describes communication between each network node at normal state and emergency state.

5. CONSIDERATION OF RESPONSE TIME

To define the polling period of the main controller for the reliable operation, it is important to know the transmission time of each message and the maximum delay time in the



(a) **(b)**

Fig. 8 Message Communication (a) normal state (b) emergency state

worst case condition. In order for all nodes to guarantee their service time, the polling period must be large than the maximum delay time. The maximum delay time means the time required to transmit its data in case of the worst condition. In this paper, the transmission rate of proposed system is fixed to 500Kbps.

5.1 Transmission time

The transmission delay time for the message with the highest priority depends on the size of data length and the transmission rate. In the CAN network, the transmission time, C_i , can be calculated as Eq. (1).

$$C_i = (n \times 8 + 47 + \left\lfloor \frac{(n \times 8 + 34 - 1)}{4} \right\rfloor) \times \tau_{bit} \qquad (1)$$

where n is the number of data bytes and τ_{bit} is the bit time. [3] From Eq. (1), the transmission times for each message frame are calculated as Table 3 where τ_{bit} is 2μs.

Table 3. The transmission time for each frame

Frame	n	Ci (μs)
Extinction	0	110
Alarm	0	110
Commend	1	130
Information	1	130

5.2 Maximum delay time

Maximum delay time is calculated as following :

$$T_{delay} = (C_{Ai} + C_{Ci} + C_{Ii}) \times k + C_{Ei} \times p \qquad (2)$$

where T_{dealy} means the total delay time, C_{Ai}, C_{Ci}, C_{Ii}, and C_{Ei} mean the transmission times for the alarm frame, the command frame, the information frame and the extinction frame respectively and also, k and p mean the number of fire detectors and actuators respectively.

For example, when the number of detectors are 100 and the number of actuators are 32, the maximum delay time is 40.52ms. This value is sufficient for the regulation of America's NFPA(National Fire Protection Association- 90 second).[4]

6. EXPERIMENT

Atmel's T89C51cc01 which has on-chip FullCAN module is used to implement of CAN based fire detection system. T89C51cc01 is CAN specification 2.0B compliant and features 15 message buffers within the internal memory range of the 8051 in the form of 34 special function registers. Because the ionization type sensor is less expensive and more reliable compared to the photoelectric type sensor, the ionization type smoke sensor is used as a fire detector which is the main detector in fire detection system and it is connected through CAN network as is shown as in Fig.9.

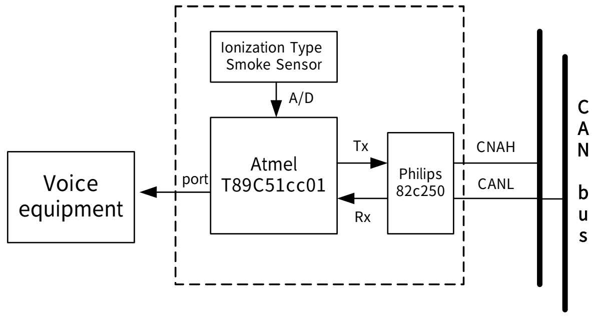
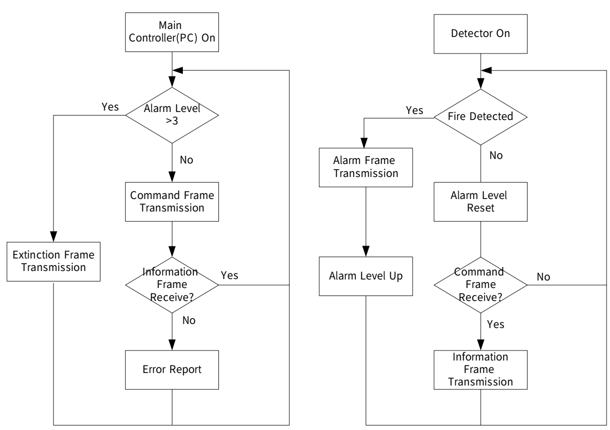


Fig.9 Configuration of fire detector system

The voice announcement equipment which is used for the fire warning is implemented with the single-chip voice recorder and playback device which has playback capability for 40 to 60 seconds. In the experiment, the transmission rate is 500Kbps and the entire system shown in Fig. 9 is composed of one personal computer as a main controller, three fire detectors and one actuator. The operation algorithm of the main controller and the fire detector are described in Fig.10.



(a) (b)

Fig.10 Flowchart of operating algorithm for fire detector system (a) main controller (b) fire detector

In this system, the polling period is 10ms, and it is enough to satisfy the time constraint.

Fig. 11 shows the transmission delay time between the alarm frame and the extinction frame.

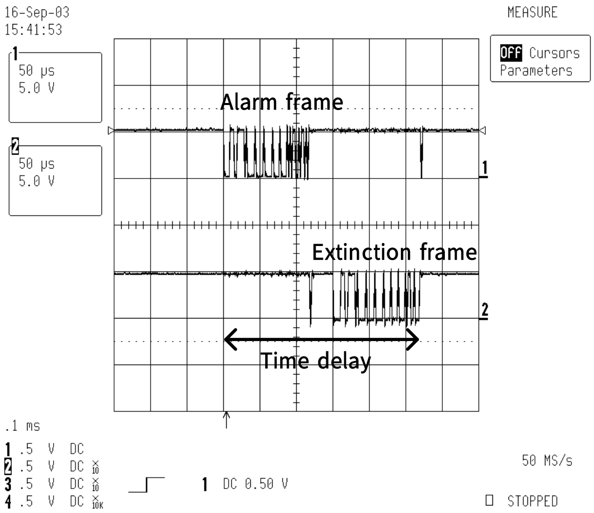


Fig.11 Time delay from fire detection to extinction (time delay=270µs)

As we can see in Fig. 11, the time delay from the experiment is similar to that from TABLE 3. The resulted delay time from the start of alarm frame to the end of extinction frame is about 270µs. Actually, this time means the time required from fire detection to fire extinction.

Fig.12 displays the analog to digital conversion signal in MMI window of main controller. In this figure, we can understand that the fire is detected at 25s, and the fire detection signal is disappears at 45s.

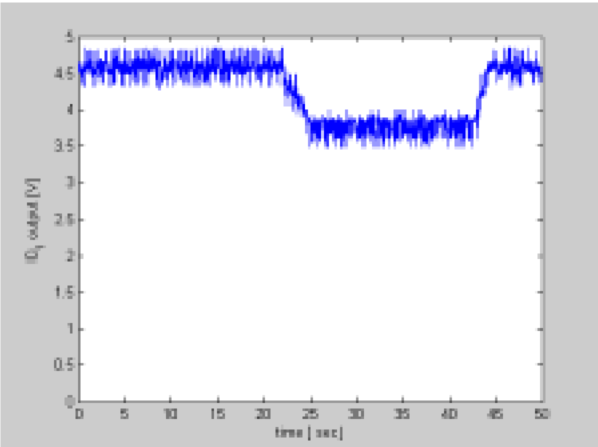


Fig.12 Analog to digital conversion data in MMI

7. CONCLUSIONS

In this paper, we propose CAN based fire detection system which has a reliable communication that can be used in buildings or apartments. The proposed system is stronger and simple than the previous one and it is sufficient to satisfy the time limit. MMI is achieved easily by replacing the traditional monitoring system with the personal computer.

Our system has the following advantages compare to the conventional system:

- Low cost
- High performance
- Easy development and maintenance
- No need for high development tool

In the near future, we can apply the CAN protocol to another building automation field. In addition, the redundancy model like two network cables and two network modules can be added to our system for the high reliability. Finally, the performance evaluation will be carried out when the system is actually installed in the building or apartment.

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