

Counting Addressing Method - False Triggering Problem

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Abstract: The specific requirements that appear in addressable fire detection and alarm systems and the shortcomings of the existing addressing methods were discussed. A new method of addressing of detectors was proposed. The basic principles of addressing and responding of a called element are stated. The sensitivity to electromagnetic disturbances is one of the greatest problems of the proposed addressing method - counting type of addressing. The proposed solutions of this problem were verified experimentally. The paper also gives the conditions and results of the experiment. The counting addressing method was developed for specific requirements in fire detection and alarm systems, yet its speed and reliability justifies its use in the acquisition of data on slowly variable parameters under industrial conditions.

Keywords: Fire detection, intelligent sensor, alarm system, computer communications.

1 Introduction

ADDRESSABILITY (the ability to recognize an address) is an element of intelligence; by adding this feature to fire detectors, we turn them into intelligent sensors. Addressability is a well-known and widely used feature, especially in computer communications. Addressability in fire detection and alarm systems has its peculiarities, as a result of which the classic and tested solutions have not turned out to be the best for this purpose.

The problem of addressability in fire detection and alarm systems has been solved by various manufacturers on different ways, and there is still no clear method which would be good enough to be accepted as a standard. The selection of addressing method in addressable systems for fire detection is a highly complex and

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difficult task, due to the peculiarities of these systems and requirements which frequently contradict each other [1].

Before we proceed discussing possible ways of addressing, we will give a list of peculiarities which make addressability in fire detection and alarm systems a challenging task.

The obligatory request in fire detection and alarm systems is power supply and communication lines for addressable element (AE) must be realized through the same pair of conductors. Communication in computer systems is realized through special communication lines. This causes an additional problem in AE - extraction of communication signals from a line powered by d.c. voltage, 24 V. At the same time, it is necessary to solve the problem of generating communication signals in the computer which generates counting pulses, polling addressable elements and interprets their responses (usually cold central station, control panel or main console) [2].

Communication requirements in addressable fire detection and alarm systems are quite reduced in comparison with computer communications, and include:

- addressing (polling AE),
- command ON/OFF (for command AE),
- Response of the called AE.

The response of an addressable element depends on the nature of the device connected to the addressable element; it can be digital (one of the two levels or states), or analog. The response of an addressable element can also include the address of the AE, which confirms the validity of addressing (this is common in computer communications). To increase calling frequency, sending the address can be avoided in the response, while the reliability of calling can be ensured in some other way; this will be discussed in more detail later.

The majority of manufacturers use lines up to 2 km [3], which is substantial. For such lengths, computer communications make use of special interfaces (current loop or RS485 up to 1,2 km) with a reduced number of ports on the line (usually up to 30). To connect a larger number of users to the line, and for greater distances, one uses optical cables (highly resistant to electromagnetic disturbances), but their price and the price of the required interfaces are high. Also, optical cables cannot supply the sensors with power.

The required number of addressable element ports on the line in addressable systems ranges from 50 (in Cerberus) to 256 (Apollo, Ziton, Zettler). Such a high number of ports in computer communications is realized through optical cables and special interfaces whose use is impossible in fire detection and alarm systems, due to their price and the need for power supply [4].

This problem can be surmounted by increasing the wires cross section (which reduces the resistance of the line), by increasing the communication signal amplitude, and by reducing detectors consumption.

As the same line is used for both power supply and communication, the consumption of addressable elements and of the detector represents an important limiting factor for line length and the number of detectors, due to lines resistance. Let the consumption of an addressable element be 0.2 mA, 24 V. For 256 addressable elements on a line with resistance 100 Ω leads to a line voltage drop is:

$$\begin{aligned}\Delta V &= 256 \times 0.2 \times 10^{-3} \times 100 \\ &= 5.12 \text{ V}\end{aligned}$$

Reduction of the consumption of addressable elements and detectors enables an increased number of detectors on the line, the use of a longer line, and a smaller cross section of the conductor.

The price of an addressable element certainly affects on the choice of the solution, and eliminates numerous better solutions (otherwise used in computer technology). The price of an addressable element in the global market ranges between 20 and 30 USD; thus, finding a more expensive solution makes no sense, regardless of its quality.

Closely related to the price and consumption is the complexity of addressable elements electronics. It is clear that the price and consumption of simpler electronics are more acceptable, and that the increase of electronic complexity involves the increase of both price and consumption. Going to a technologically higher level (full custom design) can minimize both the price and the consumption of addressable elements.

Another important element of the price of a fire detection and alarm system is certainly the price for cable needed for distribution of signals and power supply.

The use of optical cables for communication has already been eliminated, because of both their price and the price of the required interface, and the requirement to provide both power supply and communication through a single pair of conductors.

The use of cables with a protective shield, which successfully eliminates the effect of induced electromagnetic disturbances, is not acceptable because of their price, so we are left with the option of using relatively cheap cables without a protective shield. Copper conductors of cross section 0.8mm² are commonly used. The use of conductors of a larger cross section reduces line resistance, causing a line drop, which enables the line to be lengthened or to increase the number of connected addressable elements.

Owing to this requirement, when selecting an addressing method, special attention must be paid to the occurrence of disturbances, their effect on the system,

and the methods of overcoming this problem. The methods for overcoming line disturbances used in conventional computer communications cannot be applied in fire detection and alarm systems, due to their peculiarities, as we have already seen.

As a rule, when connecting a larger number of addressable elements to a line, calling is performed cyclically. In such cases, giving priority is achieved through more frequent calling of elements of a higher priority. In systems working in real time, calling rate, defined as the number of calling the same addressable element per unit time, is determined through maximal allowed time between two calls of an AE.

The classic methods of solving this problem are bit speed increase and limitation of the number of addressable elements on the line. Less frequently, the problem is solved by introducing priorities in calling.

For achieving good communication reliability, and bearing in mind line length and quality, bit speed is limited to 2400 bauds. Reduction of the number of addressable elements on the line in systems for fire detection and alarm is not an applicable method, due to the fact that it is required that the largest possible number of addressable elements is connected to the same line. Introducing priorities to addressable elements of the same nature (e.g. fire detectors) is certainly not an acceptable method.

Time between two calls in systems of 256 addressable elements on the line is 4s (Apollo-Pastor), while in systems of 127 AE this time is 2 seconds (Ziton). This clearly tells us that the problems mentioned above have not yet been solved. Some manufacturers have settled to solve this problem by reducing the number of addressable elements on the line; thus, CERBERUS has limited the number of addressable elements to 50. Time between two successive calls 2 s seems plausible, but if we take into account the time required to turn off and relax a detector before the next reading, we come to the result that the alarm will be raised no less than 6 seconds after the moment of the first occurrence of state of the alarm on the sensor. Knowing the dynamics of some fires, this time can be impermissibly long [5].

Calling rate becomes of special importance in addressable analogous systems, a subject which will not be elaborated here.

If we dismiss reduction of the number of detectors on the line as a method for shortening selection time, we are left with reduction of the time required for processing an addressable element as the only way of improving the performance of addressable and, especially, of addressable analogue systems.

2 Addressing of the Counting Type

Let each addressable element on the line has a counter and a comparator. The counter is triggered by voltage clock pulses on the line. The current counter value is compared with the pre-assigned value of the address in the comparator, and the comparator generates EQV signal when the state of the counter is equal to the pre-assigned value of the address. Figure 1 shows the basic principle of the counting method of addressing.

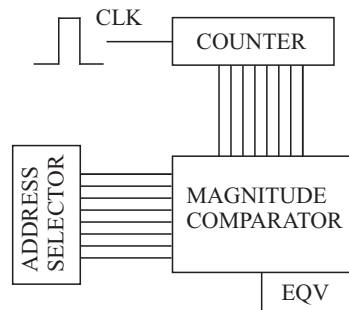


Fig. 1. Counting addressing method principle.

The host computer generates voltage clock pulses that polls all detectors announce and manages alarms - usually known as main console or control panel. After resetting the counter, all counters on the line are in the initial state. Methods of ensuring RESET and other signals will be discussed later.

As the main console generates the first clock pulse, the state of all counters on the line is 1. It is only on addressable element 1 (AE1) that the pre-assigned address corresponds to the state of the counter, and it is the only one that generates EQV. Addressable element 1 remains addressed until the next clock pulse [6].

Each clock changes the state of each counter and addresses the next addressable element. This simple way of addressing requires relatively simple electronics, which further means low energy consumption and a competitive price. This method has also turned out to be a very fast addressing method in comparison with other addressing methods [6].

The discussed addressing principle has its shortcomings, such as sensitivity to disturbances. Also, it is not clear how an addressable element will respond or react to a command. These issues will be discussed as we proceed.

3 Extraction of the Clock and Reset Signals

Degradation - the loss of initial shape - of the signal the line is a consequence of line resistance and capacitance (in the case discussed here, inductance of the line

is negligible). Figure 2 shows pulses of different widths at the output end - a), degraded pulses at the input end, - b), and pulses after reconstruction by Schmidt trigger circuit - c).

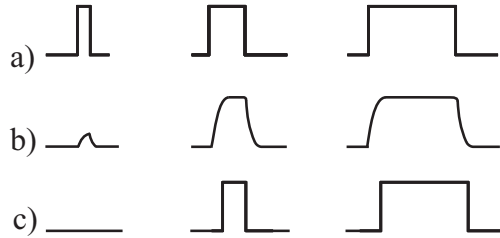


Fig. 2. Consequences of signal degradation on impulses with different widths a) basic impulses b) degraded impulses and c) reconstructed impulses.

Too short pulses (first column) resulting from degradation cannot reach the triggering level of the Schmidt trigger, and cannot be reconstructed. This also applies to low-level and short-term disturbances.

Sufficiently long pulses will be narrowed and delayed due to degradation by the line (second and third columns).

Signal measurement on a line of length 1.5 km (conductor cross section 0.5mm^2 , resistance 90Ω) has shown that pulses longer than $7\mu\text{s}$ can be successfully transmitted.

For achieving greater transmission reliability, we have adopted that the clock pulse is $30\mu\text{s}$. In this way, we have ensured high reliability of triggering counters in the addressable elements on the line.

Figure 3 shows the clock and RESET pulse extraction block from the distribution and power supply (24 V) line, to which clock and RESET pulses (amplitude 5V, different durations) are added.

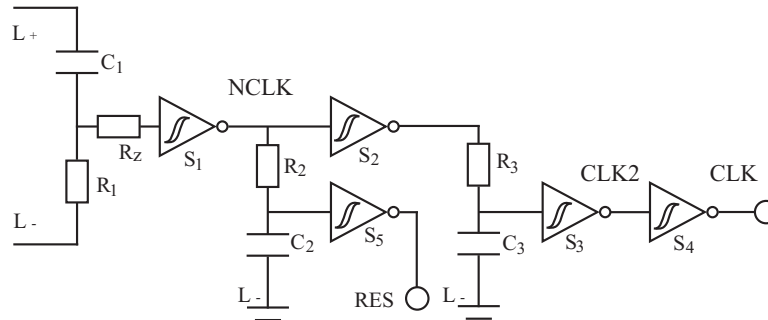


Fig. 3. Extraction from the line and forming signals CLK and RES.

Integrative element C_1R_1 extracts pulses from the line. Resistor R_z serves as a

protection of Schmidt trigger S_1 that shapes and inverts the input pulse (NCLK in Figure 3).

The charge of capacitor C_2 through resistor R_2 also serves to shape the RES signal for the counter. Pulses of short duration (clock pulses) are insufficient to fill the capacitor (C_2), and cause no change to RES signal. Resetting of counters in the addressable elements is performed by prolonged pulse on the line (1 ms) sufficient to fill capacitor C_2 and generate the signal for resetting of counters - RES.

Schmidt trigger S_2 has the task to extract time constant R_2C_2 from R_3C_3 . Values R_3 and C_3 have been selected so that the clock pulse is narrowed by additional $15\mu s$, which brings the duration of the CLK pulse within $10 - 15\mu s$. Thus, pulses of duration up to $15\mu s$ do not trigger the counter. As pulse disturbances on the line are usually shorter than $15\mu s$, we have an addressable element protected against undesired counter triggering and misaddressing.

4 Response

Any of the detectors connected ought to recognize its address and give one of the following responses: detector in state of alarm, detector in normal state, detector is not present.

In the previous Section, we discussed the block for extracting the pulse from the line, before the basic principle of addressing was explained.

The block scheme of the addressable element is represented in Figure 4.

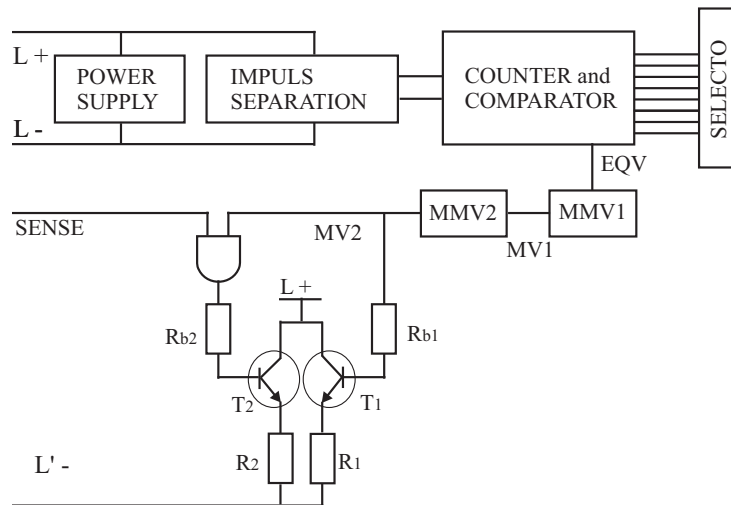


Fig. 4. Block scheme of the addressable element.

When a detector is not present, SENSE and L'_- are not connected. When a

detector is connected, L'_- and L_- become connected, while SENSE contains information on the state of the detector.

Let us now see what happens in the addressed detector.

- Output signals from mono-stable multivibrators MMV_1 and MMV_2 are marked as MV_1 and MV_2 . In the given configuration, transistors T_1 and T_2 behave as d.c. current sources bringing signals high to their bases.
- EQV signal remains high until the next counting pulse - 1 ms.
- The leading edge of the EQV signal triggers mono-stable multivibrator MMV_1 , whose relaxation time is chosen to be $300\mu s$. The trailing edge of MV_1 signal triggers mono-stable multivibrator MMV_2 , whose relaxation time is approximately $400\mu s$.
- High level of signal MV_2 activates d.c. current source T_1 , so that the line current is 5 mA.
- High level of signal MV_2 enables SENSE signal through the logical AND circuit, and high level of SENSE signal then activates o.k. current source T_2 (5 mA).
- To summarize, 5 mA current causes the response of the addressable element with the detector in the normal state; if the detector is in the state of alarm, the line current is doubled - 10 mA.
- Absence of the detector prevents any current flow, since L_-' is connected to the line within the detector itself.
- The use of variable d.c. current sources ($4 \div 20mA$) for transfer of analogue values is often used in industrial equipment and instrumentation, due to their small sensitivity to electromagnetic disturbances.

5 Experimental Verification

The addressable element and adequate control panel with the corresponding software have been developed for experimental verification of the proposed concept of addressable system for fire detection and alarm.

The block scheme of the addressable element is given in Figure 4.

To check the efficiency of the method used to prevent influence of pulses narrower than $15\mu s$ (see Section 3), we performed the measurements with addressable elements and phantom receivers [6] (addressable element in the control panel which purpose is to compare number of generated and received counting pulses) without limitation of the triggering pulse and with limitation of the duration of the triggering pulse.

For this experiment, a system of 25 addressable detectors and a control panel were realized.

Apart from the software that has already been mentioned, additional software was also made, for counting:

- false triggering of the phantom receiver,
- refused (not confirmed in the next poll cycle) responses.

The special archive in operating memory enables determination of the number of alarm states (even of false alarm states), as well as the number of recorded disturbances on the line (two adjacent refused responses).

The experiment was performed on a two-wire line (the line of fire signalization), whose length was 1.5 km, cross section of the conductor 0.5mm^2 . As it is common practice to use conductors of cross section 0.8mm^2 or more, we can assume that the experimental conditions were harder than in real cases. The line was stretched between power cables, the rules regarding distance were not obeyed, which contributed that the conditions on the line were harder than in real cases.

The parameters of the line impedance were determined by measurement:

- Resistance $R = 90\Omega$,
- Capacitance $C = 40\text{nF}$,
- Inductance $L = 6\text{mH}$.

5.1 First experiment sending of pulses along the line

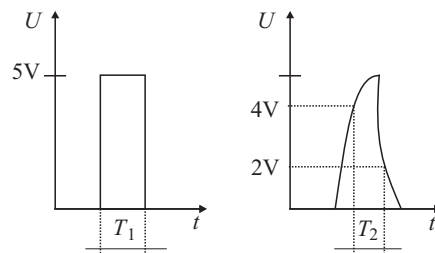
Pulse generator HP 3466A was used to generate pulses of varying duration and frequency (duty cycle 10%), amplitude 5 V. At the terminal part of the line, digital oscilloscope GOULD was used to observe the signals. The width of the transferred signal was measured between the moment of reaching 4 V for the leading edge and 2 V for the trailing edge (Figure 5). These levels were taken due to the hysteresis of the Schmidt trigger.

The results of this experiment are given in the table in Figure 5. Signals of width $7\mu\text{s}$ cannot be reconstructed, but they are close to triggering the counters in the addressable elements. The signals longer than $8\mu\text{s}$ are reconstructed successfully.

These results were used to specify the width of the clock pulse of $30\mu\text{s}$, which is successfully transferred through the line and has enough space to narrow down the pulse in the addressable element itself by $15\mu\text{s}$ at the counter input.

5.2 Second experiment operation in the presence of disturbances

Further experiment was operation in the presence of disturbances. The disturbances were generated turning on /off:



T_1 (μ s)	T_2 (μ s)	COMMENT
1		reaches 2V
2		reaches 2.87V
3		reaches 3.29V
4		reaches 3.57V
5		reaches 3.70V
6		reaches 3.85V
7	1.40	
8	7.70	
9	8.60	
10	9.60	
15	14.40	
20	19.10	
25	24.20	
30	29.30	
50	49.40	
100	102	
500	503	
1000	1018	

Fig. 5. Shape and width of the pulses at the beginning (T_1) and at the end (T_2) of the line.

- A larger number (about twenty) of neon lamps (in one bureau),
- Drilling machine (400 W),
- Soldering bits (40 W),
- Power source HP 3586BA (800W).

A typical form of all these disturbances is shown in Figure 6. The overall length of induced disturbances (T_2) ranges from 450μ s for the drilling machine to 1.5ms for the power source. The width of pulse T_1 ranges between 2.5μ s for the power source to 8μ s for the drilling machines.

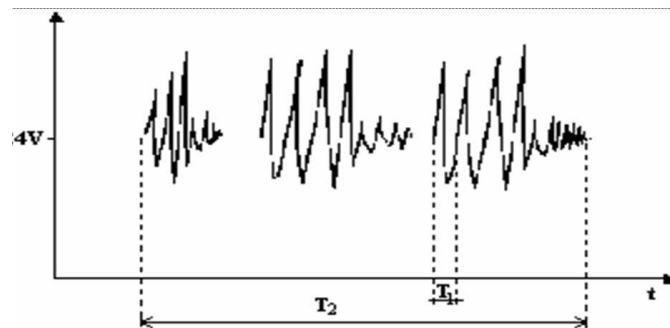


Fig. 6. Shape of disturbances.

The first group of experiments was performed with addressable elements and a phantom receiver, whose clock pulses were reconstructed from the line without

discriminating pulses shorter than $15\mu s$.

The experiment consisted of performing 100 changes of state for each respective device (50 times turned on and 50 times off).

Table 1. The experimental results without limitation of the clock pulse.

source of disturbances			Detectors and sources at the beginning / end of the line							
			number of changes	false triggering of the phantom receiver		refused responses		false alarm		
description	T_1 (μs)	T_1 (μs)		total	per change	total	per change	total	per change	
drilling mashine	8	450	100/100	26/20	0.26/0.20	20/18	0.20/0.18	0	-	
group of neon lamps	2.5	700	100/100	98/14	0.98/0.14	58/14	0.58/0.14	0	-	
soldering bit	6	500	100/100	17/3	0.17/0.03	15/5	0.15/0.05	0	-	
power source HP	2.5	1500	100/100	96/18	0.96/0.18	86/43	0.86/0.43	0	-	

During this period, special software was used to memorize the number of false triggering of the phantom receiver and the number of refused responses. The archive provided the number of false alarms.

Two sets of measurement were performed:

- 25 detectors were at the beginning of the line (near the control panel),
- 25 detectors were at the end of the line (away from the control panel).

In both cases, the sources of disturbances were near the detectors. Measurement results are shown in Table 1.

According to decision algorithm, to declare change in the state of detector two same subsequent responses of the same addressable element must be received. When a sequence of responses “old state–new state– old state” from the same addressable element happens, response “new state” will be refused.

Refused responses were caused by electromagnetic disturbances.

After receiving the response, the status of phantom receiver is checked. When status was different from expected, consequence is counted as “false triggering of phantom receiver” .

Both consequences could be counted from one electromagnetic disturbance.

The results of these experiments indicate the following:

1. The selected sources of disturbances generate disturbances of intensity sufficient to cause false triggering of the phantom receiver and refused responses.
2. No false alarms were raised, i.e. the disturbances merely slowed down the system, which proves the validity of the mentioned decision algorithm [6].

3. The number of false triggering of the phantom receiver and the number of refused responses are strongly influenced by the location of disturbance generators (when the detectors and sources are at the beginning of the line).

The next set of experiments was performed after changes to the addressable elements and the phantom receiver were made. The purpose of this change was to prevent pulses shorter than 15 s from triggering counters in the addressable elements and the phantom receiver (see Section 3).

The disturbances were caused by the same devices and under same conditions. The results of the next set of experiments are given in Table 2.

Table 2. The experimental results after elimination of clock pulses shorter than $15\mu\text{s}$.

source of disturbances			Detectors and sources at the beginning / end of the line						
			number of changes	false triggering of the phantom receiver		refused responses		false alarm	
description	T_1 (μs)	T_1 (μs)		total	per change	total	per change	total	per change
drilling mashine	8	450	100/100	0	-	58/42	0.58/0.42	0	-
group of neon lamps	2.5	700	100/100	0	-	176/35	1.76/0.35	0	-
soldering bit	6	500	100/100	0	-	48/12	0.48/0.12	0	-
power source HP	2.5	1500	100/100	0	-	182/78	1.82/0.78	0	-

The following can be noticed:

1. Disturbances which nearly always caused false triggering of the phantom receiver no longer did that.
2. The number of refused responses has considerably increased. The disturbances which earlier caused triggering of the phantom receiver were not the only cause for responses to be refused. It is often the case that one long disturbance causes two refused responses. This explains the number of refused responses which is considerably higher than the number of changes.
3. The number of refused responses depends, to a large extent, on the location where the disturbances occur. This was also noticed in the previous set of experiments.
4. No false alarm was raised, which was to be expected.

From the last set of experiments, it can be concluded that the mentioned decision algorithm are sufficient and the use of the phantom receiver is not necessary.

6 Conclusion

The performed set of experiments has confirmed the validity of the discussed concept. The counting method of addressing, otherwise highly sensitive to distur-

bances, could be made usable, by applying the discussed methods.

The response time of the system is far better than that of the conventional digital addressing method, which justifies the effort invested in this research.

After experimental verification, a special chip (custom design) was made, which implements the proposed addressability concept.

The addressable control panel for fire detection and alarm was also made, based on the proposed hardware and software solutions.

Having in mind a significant increase of the calling rate, the proposed addressability concept enables development of addressable analogue systems, where decisions can be made not merely on the basis of the achieved level of detector analogue value, but also on the basis of the rate of change of the analogue value.

The proposed addressability concept can also be applied for acquisition of slowly varying data (temperature, humidity, etc.) when sensors are at considerable distance from each other.

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