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A small local computer network for automation of manufacture and scientific researches

O. Nicolaiciuc, E. Guţuleac, V. Cheibaş

Abstract

The factors are described that determine the development of small automation systems of operations and research, designed for use in small production companies and research centers. Basic system requirements are outlined, **LAN** configuration is described, **MGT** scheme is presented, the formats of command and answer-back frames are described.

1 Introduction

Falling prices of personal computers (**PC**) and development of microcontrollers by the world leaders in microcomputing, in particular a dramatic increase of data transmission speed of the embedded **UART**, all these have prepared the ground for the creation of small specialized command-informational local area networks (**LAN**) for purposes of manufacturing and research automation, integrating one **PC** and up to 16 peripheral microcontrollers.

Under such organization, the **PC** plays a role of the tasks generator and data receiver, it carries out secondary data processing, sorting, saving and visualization of data.

The peripheral microcontrollers carry out measurements of the analog and digital data from various gauges and preliminary data processing, operate various external devices, test their subsystems and communicate with the **PC**.

The main requirements towards such small networks include low cost, structural simplicity of organization and high reliability.

Development of such systems with the help a traditional **LAN** based on the **RS232C** protocol is complicated by fact of one **PC** giving out tasks to several controllers, which makes it necessary to use either a "star" or a "ring"-type connection. In the first case, in addition to a standard configuration **PC** it is necessary to maintain an internal or external switchboard for the **RS232C** channel. On the other hand, in the case of a "ring" each peripheral controller must have an appropriate **RS232C** translator.

It is also possible to create a network with the **RS485** or other network protocol. However, in such a case the cost of the system will increase significantly due to the more expensive network environment, and because of the need to provide a **PC** network card, and the appropriate built-in network interface for each of the peripheral controllers.

Besides, in a modern specialized **LAN** for purposes of automation of technological processes and research operating under conditions of strong industrial electromagnetic noise and other extreme operating conditions, a necessary condition would be an **Optical Isolation** of at least 500V, which is complicated enough for a standard **LAN**. A cardinal solution is the use of an optic- fiber environment **LAN**. However, such a solution would be very expensive even given a relatively small physical area of the network.

2 Requirements to LAN

The above analysis allows formulating the requirements to a specialized small command-information **LAN** for the purposes of automation of operations and research [1]:

- Specialized **LAN** should be as cheap and simple as possible both in installation and use;

- Specialized **LAN** should have a **PC** of standard configuration, i.e. equipped with one free **RS232C** interface;
- Each peripheral controller should be equipped with a simple interface **RS232C** with **Optical Isolation** protection of 500V;
- Number of peripheral controllers in a network – up to **16**;
- Length of transmission medium – up to **20** meters (**70** feet);
- For reasons of simplicity of installation and use it is desirable to use standard **RS232C** cables as a transmission medium;
- During development of a specialized **LAN** it is necessary to ensure:
  - reception of the tasks by any peripheral controller from the **PC** working as a task generator;
  - on-demand reception of measurement results by the **PC** from any peripheral controller;
  - self-testing by any peripheral controller on the **PC** demand with the transfer of testing results back to the **PC**;
  - hardware reset of all peripheral controllers on the **PC** demand;
  - reception by **PC** of the emergency information initiated and generated by any peripheral controller.

In view of the above requirements, the authors created a specialized **LAN**, the organization of which is shown on Fig.1.

3 LAN Configuration

The developed **LAN** structure includes: 1 **PC** of standard configuration and up to 16 peripheral controllers (**Station 1 . . . N**). As a

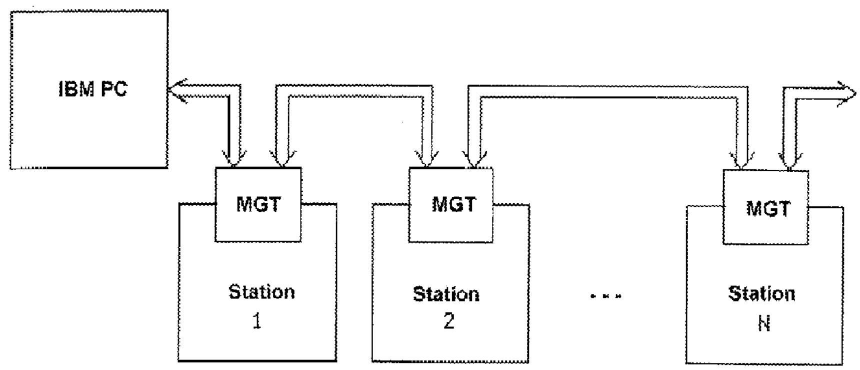

Fig.1 Organization of specialized **LAN**

transmission medium – standard shielded cables are used of 1, 2 or 1, 5 meters in length with two identical standard 9-pin **DB9** computer connectors. Each station is equipped with a **Station Management** circuit (**MGT**), an interface unit which communicates between the **Station** and the **Transmission Medium**. Every **MGT** has 2 **DB9** block sockets connected in parallel. This way the **Transmission Medium** consists of **N** standard consecutively connected cables. Overall length of a **16** stations **LAN** would be. i.e. $16 \times 1,2 = 19,2$ m. The specialized **LAN** described above is a bus network with a linear configuration using the basic strip of frequencies (**Base-band LAN**).

4 MGT unit

The basic circuit of a **Station Management** unit is shown below (Fig.2).

In the Fig.2 one X1 **DB9** block socket is described, while each station has two such sockets connected in parallel. Six **RS232C** interface lines are used: one **TxD** (Transmitted Data) line used as described – to send data from the **PC** to the stations and through the **VD1**

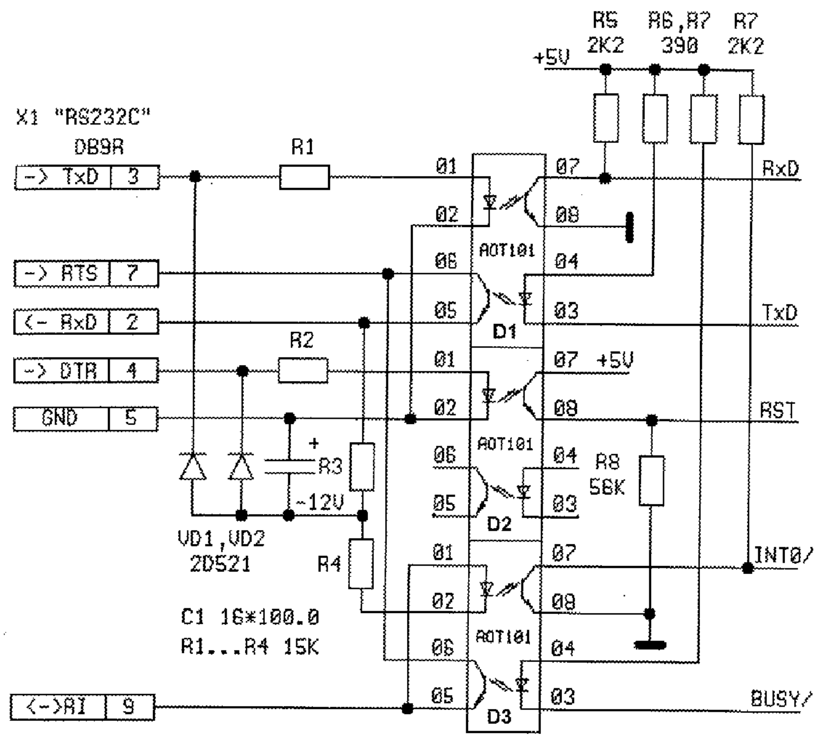

Fig.2. The Station Management Unit (**MGT**)

diode to form a negative voltage on the **MGT**; one **RxD** (Received Data) line used as described – to receive data from stations; one **RTS** (Request To Send) line used as a source of a positive voltage on the **MGT**; one **DTR** (Data Terminal Ready) line used to generate a reset (**RST**) signal for all network stations simultaneously and through the **VD2** diode to form a negative voltage on the **MGT**; one **RI** (Ring Indicator) line to generate a busy signal; and a common (**GND**) line.

The operating principles of **MGT** are fairly simple. At all times of **LAN** operation the **DTR** line must be set at Boolean "**0**", i.e. its voltage under the **RS232C** standard should be from −15V to −3V.

This voltage is passed on through the **VD2** diode to the **C1** capacitor where a negative voltage is created on the **MGT**. In addition, when a Boolean "**0**" is present on the **TxD** line, a negative voltage is similarly passed on through the **VD1** diode to the **C1** capacitor. To reset all the stations simultaneously the **DTR** line is used for the period of $1-3$ mS when it is set to the Boolean "1". This signal turns on higher **LED** of the **D2** optical unit through the **R2** resistor. The respective optical transistor is turned on and a positive **RST** pulse appears at the **R8** resistor, which is passed on to the microcontroller.

Data transfer from the **PC** occurs through the **TxD** line via the **R1** resistor and the higher **LED** and optical transistor of the **D1** unit. From the transistor collector the signal is passed on to the microcontroller.

Data transfer from a station occurs through the lower pair of **LED** and optical transistor of the **D1** unit, the necessary target output levels on the **RxD** line being created due to the following connection. The lower transistor collector (on **D1**) is connected to the **RTS** (positive voltage) line. The transistor emitter is connected through the **R3** resistor with a negative voltage from the **C1** capacitor.

BUSY/ signal is generated by a station microcontroller and sent through the lower pair of **LED** and optical transistor of the **D3** unit, which is passed on to the **RI** line. A special feature of the output unit is the connection between the lower optical transistor collector of the **D3** unit and the **RTS** (positive voltage) line, while the emitter is connected through the higher **LED** and the **R4** resistor to the negative voltage from the **C1** capacitor. Such a connection turns on the higher pair of **LED** and optical transistor of **D3** unit of all stations whenever one of them sends a **BUSY/** signal.

The values of **R1-R4** resistors are selected so as to provide a normal loading of the output lines of the **RS232C** interface at parallel connection of up to 16 stations. When **D1-D3 101** optical microchips are used with the overall transmission medium length of up to 20 meters a Serial Speed of $28,8$ Kbit per sec is achieved.

5 Frame I/O formats

Let's consider the Medium Access Control Protocol. Since the exchange is initiated by the **PC** and the receivers are the station microcontrollers, the use of standard frames is inappropriate due to their excessive length and relative complexity of their processing. The considered **LAN** uses the following the format of commands (see Table.1).

Table.1. Command Frame Format

No	**FRAME FIELD**	**MEANING**
B1	Preamble	10101010
B2	Address of Station	Address
B3	Command Code	Code
B4	Low Data Byte	Low Data Byte
B5	High Data Byte	High Data Byte
B6	Control Sum	$\sum(B1 \ldots B5)$

If in a command the data is absent, the appropriate fields carry zeroes. After receiving the command frame and performing the task the target station sends a message formatted is per Table.2. In case of an emergency occurrence the station also sends the **PC** a message of the same format. In case of the absence of errors and/or data, the appropriate fields carry zeroes. In case of an emergency the error code and two detailed codes are transmitted in the data fields.

Table.2. Station Message Frame Format

No	**Frame Field**	**MEANING**
B1	Preamble	10101010
B2	Station Address	Address
B3	Error Code	Code
B4	Low Data Byte	Low Data Byte
B5	High Data Byte	High Data Byte
B6	Control Sum	$\sum(B1 \ldots B5)$

In case of a command transmitted by the **PC** the described **LAN** becomes a Multicast **LAN**. When an emergency occurs in one or several stations the **LAN** becomes a **Carrier Sense Multiple Access with Collision Detection** network. The following emergency handling mechanism is used: in a normal mode **PC** sends a command frame to the target station. The target station detects its address and sets a **BUSY/** signal. If necessary, the latter signal can be also detected by all stations on the **INT0/** line.

In case of an emergency occurrence in one of the stations the station waits for the clearing of the **BUSY/** signal, then sets its own **BUSY/** signal and sends the error message to the **PC**. When the **PC** detects the **RI** signal, it interrupts the main program and takes an appropriate action. If several stations simultaneously send error messages, the **PC** detects data a transmission error, sending the frame of a Jam Signal to all stations. After receiving a Jam Signal each station simultaneously attempts to send the emergency signal after a truncation period (slot-time) equal to the individual station number times (x) one frame transmission period. If the conflict persists, **PC** hardware-resets (restarts) all stations and begins their consecutive testing.

6 Conclusions

The described **LAN** is designed for creation of small automation systems with various applications in research centers and small manufacturing companies. Given the limited number of stations and few commands for each station, the frame format can be further simplified by combining in one byte the codes of the station address and the command/error code thus increasing **LAN** efficiency. Besides, depending on the **LAN** purpose, it is also possible to send only one data byte in a command and answer frames. Such simplification of the frame format reduces transmission time by 30%. The **LAN** is easy to install and operate, it has high flexibility and can be easily modified.

References

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O.Nicolaiciuc, E.Guţuleac, V.Cheibaş,
SEC "Informinstrument SA",
Str.Puşkin,6
MD2012
Phone: +373–2–240–505
e-mail: onic@ch.moldpac.md

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