Software Setting Telephone Links Using ATMEL Microcontrollers in Time Switching Network PABX

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Abstract – The work briefly presents the resources of a low capacity telephone exchange with temporal switching, using PCM encoding for the conversation signal, then the stages for performing local, outgoing and incoming telephone links. Based on these stages, macro-states graphs were designed to model the processes that perform telephone links and then used to write the command software using the assembly language for ATMEL family microcontrollers.

Keywords: macro-states graph, local telephone link, outgoing telephone link, incoming telephone link, command software.

I. INTRODUCTION

The process of establishing a telephone connection through a low capacity electronic telephone exchange (PABX) is a complexe sequential process. A graph of states must be used in order to describe it. The transitions between states are induced by certain events, which are a generalisation of the input signal, meaning that they can be input signals and/or the result of system internal processing.

It is practically proven that the graph describing a software real-time telephone connection, using periodic interrupt operation, includes very many states. Moreover, using this description, complex problems emerge while implementing the services.

Analysing the steps of performing local, outgoing and incoming telephone links, it results that certain steps are repeated several times, having different initial or final data.

Based on these facts, there were defined macro-states, which perform the steps of establishing a telephone link, such as: receiving the pulse selection information, determining the type of the call, checking the selection information, establishing (interrupting) the connection, transmitting (interrupting) a tonality, a vocal message etc.

The macro-states are designed so that they can be called from any program sequence and they return to any program sequence also

This last facility allows a very simple succession of macro-states and a simple development of telephone services.

II. THE RESSOURCES OF THE LOW CAPACITY ELECTRONIC TELEPHONE EXCHANGE WITH TEMPORAL SWITCHING

The general structure of a low capacity electronic telephone exchange is presented in figure 1, where the notes have the following meanings:
I - interface to the external medium;
CIA - individual subscriber circuits;
CJ - junction circuits;
RC - temporal connection network;
MT - tones and calling signal machine;
μC - microcontroller;
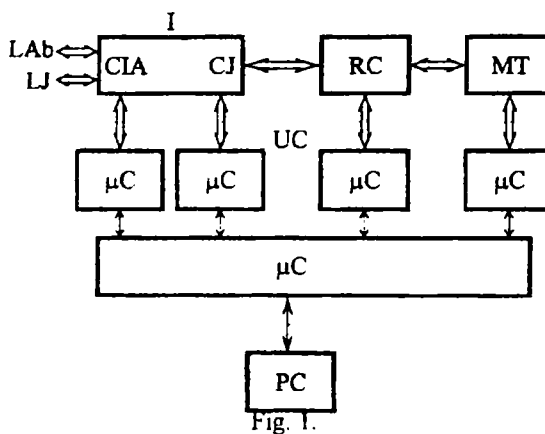UC - command unit:
PC - personal computer.

Fig. 1.

The external medium includes the subscribers' lines (LAb) through which the subscribers' telephone sets are connected to the exchange, and the junction lines (LJ) through which the exchanges themselves are connected. This interface performs the following functions: monitoring the lines, receiving and transmitting the selection information, supply, adapting, galvanic separation, protection, testing and processing the conversation signal which consists of sense separation, filtering, sampling and holding, analogic-digital and digital-analogic conversion. These last functions are implemented with TCM29C13N integrated PCM codecs.

The interface to the external medium consists of the

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individual subscriber circuits and the junction circuits. CIA performs the interfacing of the subscribers lines to the exchange and the following functions, from the point of view of the command software:

- detects the apparition of a call from a subscriber when closing the DC loop;
- receives the pulse selection information by converting the line pulses in TTL-leveled voltage pulses;
- transmits the calling signal to the subscribers.

CJ performs the interfacing of the urban telephone exchange lines to the low capacity exchange and the following functions, from the point of view of the command software:

- detects the apparition of a call from a distant exchange;
- receives the DTMF selection information from a subscriber connected to a distant urban exchange for automatic processing the incoming calls;
- transmits the calling signal to the distant exchange;
- transmits the pulse and DTMF selection information to a distant urban exchange for automatic processing the outgoing calls.

For the reception and the transmission of the tone selection information, specialized integrated circuits (M8880) are used as they are performing these functions with a minimal need for supplementary hardware.

The temporal connection network has no internal blocking and performs the switch of any channel from any input PCM line in any channel in any output PCM line.

The network is implemented using digital integrated temporal switch MT8980 which features 8 PCM input and 8 PCM output lines, each consisting of 32 channels, so that the switch has a capacity of 256 x 256 channels. The tones machine sends towards the subscribers all the signals required for the exchange's operation (dialing tone, busy, reverse call, unexisting number, warning, false call etc.), through the exchange's connection network, as well as the calling signal. MT can also send to the subscribers various information vocal signals.

The digital switch which implements connection network includes, from the point of view of the command software, a control register, a data memory (256x8 bits) and a command memory (256x11 bits) which includes a low section (256x8 bits) and a high section (256x3 bits). By programming the control register, the data and command memory can be written and read and, therefore, any link between any two subscribers can be performed, as well as any tone or vocal message can be transmitted to any subscriber.

The distributed command unit of the low capacity electronic telephone exchange is implemented using several ATMEL family microcontrollers hierarchized on two levels of priority.

On the lower level are the peripheral microcontrollers that control the individual subscriber circuits, the junction circuits, the temporal connection network, the tone machine and perform a large amount of simple but critical in time command and control operations. On the upper level is placed a main processor that performs the connection settings and telephone services. The user has access to the command unit through a personal computer that communicates serially with the main processor.

III. STEPS OF PERFORMING A LOCAL TELEPHONE LINK

Performing a local telephone link between subscribers A and B (assuming that A is the calling subscriber while B is the called subscriber) includes the following steps:
- in the first moment, subscriber A is standing by;
- subscriber A picks up the receiver in order to initiate a telephone conversation; the DC loop is closed, which performs the subscriber's A call to the exchange;
- after this call, the exchange connects the calling subscriber to the command unit, so that the selection information can be received;
- subscriber A receives the dial tone which constitues an invitation to the transmission of the pulse or tone selection information;
- the selection information transmission is initiated;
- the dial tone transmission is interrupted;
- the first digit of the selection information is received and processed;
- after receiving the first digit, the type of telephone link is determined (local, outgoing or service);
- if the first digit received is different from 9 and 0, it is a local telephone link and the reception of the other digits in the selection information is continued;
- after receivig the selection information, the number is verified, which means to determinate whether the called subscriber exists, if the connection between the two subscribers can be performed and if the called subscriber is free;
- if the called subscriber's number does not exist, then an unexisting number tone is transmitted towards the calling subscriber;
- if the telephone connection cannot be performed, then a busy exchange tone is transmitted towards the calling subscriber;
- if the called subscriber is busy, then the busy tone is transmitted towards the calling subscriber;
- if the number transmitted exists, the connection can be performed and the called subscriber is free then the reverse call tone is transmitted towards the calling subscriber and the calling signal is transmitted towards the called subscriber;
- if, after a certain time interval, the called subscriber answers, then the transmission of the reverse call tone and the calling signal is interrupted;
- afterwards, the connection between the two subscribers is commanded;
- after performig the connection, the subscribers start their conversation, and the system awaits for one of the subscribers to hang up;
- after the conversation is finished (one of the subscribers hangs up) the connection between the subscribers is interrupted;
- the system returns to the initial status.

From each step of this process, the selection information for a certain telephone service can be received and also each subscriber can hang up, and the process returns to the initial status.

IV. THE MACRO-STATES GRAPH FOR THE PROCESS OF ESTABLISHING A LOCAL TELEPHONE CONNECTION

In fig.2 is shown the macro-states graph for the process of establishing a local telephone connection through a low capacity electronic telephone exchange, using the steps described above.

Fig. 2.

The macro-states were defined as follows:

M_0 - macro-state for receiving the pulse and tone selection information;

M_1 - macro-state for determining the type of call (local, outgoing, service);

M_2 - macro-state for processing the selection information;

M_3 - macro-state for establishing the connection between the two subscribers;

M_4 - macro-state for interrupting the connection between the two subcribers which were in conversation;

M_5 - macro-state for transmitting to a subscriber a tone signal or the calling signal;

M_6 - macro-state for interrupting the transmission of a tone signal or of the callig signal;

M_7 - macro-state for waiting the standing-by calling subscriber;

M_8 - macro-state for waiting the calling subscriber which picked up the receiver has to initiate an action;

M_9 - macro-state for waiting the calling subscriber which has picked up the receiver has to initiate an action and the standing-by called subscriber to answer the call;

M_A - macro-state for conversation; it is a waiting macro-state while the two suscribers have the receivers picked up;

M_B - macro-state for waiting the interruption of the telephone connection.

The events are represented on the graph's arches and have the following meanings:

a - subscriber A has picked up the receiver;

p - specific processings for the current macro-state;

i - the reception of the selection information;

t - time counting;

cl - first digit received;

ni - unexisting number;

l - the connection can be performed;

b - subscriber B has picked up the receiver;

AE - outgoing call;

S - telephone service;

AL - local call.

Using the macro-states and the events defined above, the process of performing a telephone connection through a low capacity electronic telephone exchange can be followed on the graph. Every macro-state includes severals states and the evolution between these is depicted also by a graph of stages.

V. STEPS OF PERFORMING AN OUTGOING TELEPHONE LINK

Performing an outgoing telephone link between subscribers A and B (assuming that A is the calling subscriber connected to the low capacity exchange while B is the called subscriber of the distant urban high capacity exchange) includes the following steps:

- the first eight steps are the same as in the situation when a local link is performed;

- if the first digit received is 0, it is an outgoing telephone link;

- the first free junction line is located and engaged;

- if no junction line is free, the calling subscriber is sent the busy tone;

- if there is a free junction line, the conversation link is established between the calling subscriber and the junction line;

- the calling subscriber receives a dialling tone from the distant urban exchange;
- the pulse selection information is received from the calling subscriber and it is DTMF transmitted to the exchange;
- the state of the calling subsriber is monitored;
- if the calling subscriber hangs up, the conversation link is interrupted and the junction line is released.

From each step of this process, the selection information for a certain telephone service can be received and the calling subscriber can hang up, and the process returns to the initial status.

VI. THE MACRO-STATES GRAPH FOR THE PROCESS OF ESTABLISHING A OUTGOING TELEPHONE CONNECTION

In fig.3 is shown the macro-states graph for the process of establishing an outgoing telephone connection.

Besides the macro-states M_0 - M_B defined in previous paragraph, a few more macro-states were defined as follows:

M_C - macro-state for locating a free junction line;
M_D - macro-state for occupying the junction line;
M_E - macro-state for transmitting a digit to the distant exchange.

The events are represented on the graph's arches and have the meanings mentioned in paragraph 4 with additional two:

J - status of the junction line;
c - digit of the DTMF selection information.

Using the macro-states and the events defined above, the process of performing an outgoing telephone connection can be followed on the graph.

VII. STEPS OF PERFORMING AN INCOMING TELEPHONE LINK

Performing an incoming telephone link between subscribers A and B (assuming that A is the calling subscriber connected to the distant urban high capacity exchange, while B is the called subscriber of the low capacity exchange) includes the following steps:

- the calling subscriber A picks up the receiver, receives the dialling tone and transmits the telephone number for calling the low capacity exchange on the junction line;
- if the called junction line is free, the urban exchange sends the reverse call tone to subscriber A and calling signal on the junction line.

These steps are performed by the high capacity urban exchange.

- the junction line is free and awaits an incoming call;
- when the call is received, the junction is engaged and from the urban exchange, the transmission of the reverse tone and of the calling signal is interrupted;

- the low capacity exchange transmmits from the tone machine to subscriber A a vocal information message (e.g. "You called the Technical University. Please dial the interior number desired."), then the dialling tone;
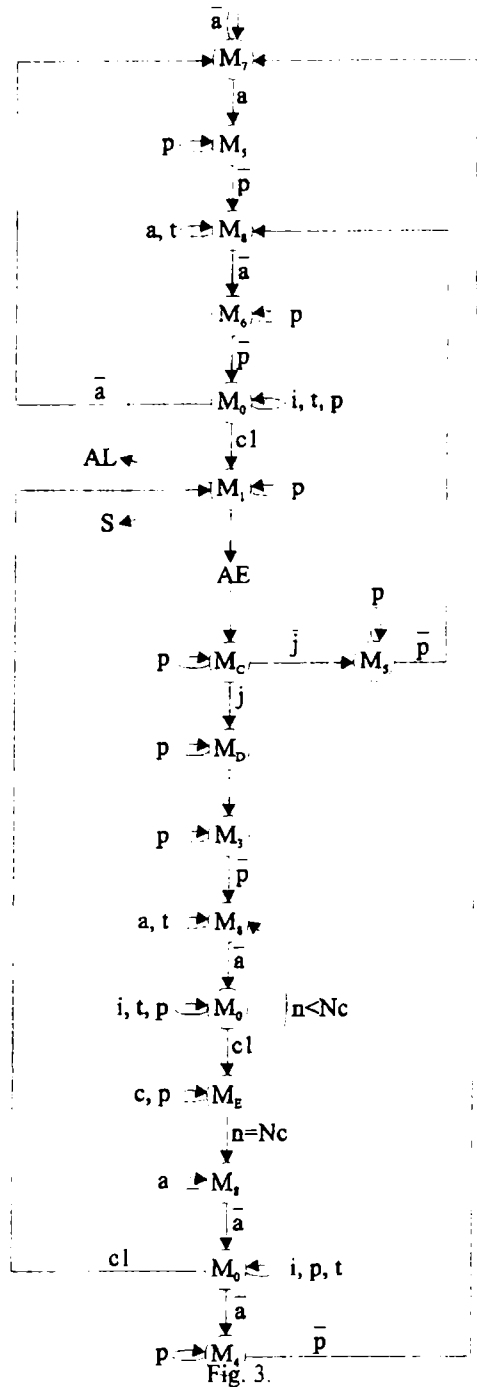

Fig. 3.

- the beginning of the DTMF selection information transmission is awaited;
- if during a pre-set time interval (e.g. 20 seconds) the transmission of the tone selection information does not start, then the dialling tone transmission is canceled and the subscriber A is connected to a duty subscriber or to the exchange's operator, which performs the link required;
- if the DTMF selection information reception started, the dialling tone transmission is cancelled and the selection information is fully received and then

processed;

- if the called subscriber's number does not exist, then an unexisting number tone is transmitted towards the calling subscriber;

- if the telephone connection cannot be performed, then an busy exchange tone is transmitted towards the calling subscriber;

- if the called subscriber is busy, then the busy tone is transmitted towards the calling subscriber;

- if the number transmitted exists, the connection can be performed and the called subscriber is free then the reverse call tone is transmitted towards the calling subscriber and the calling signal is transmitted towards the called subscriber;

- if the subscriber B does not answer in a specified time interval (e.g. 40 seconds) the transmission of the reverse call tone and the calling signal is interrupted and, after a vocal warning message, the junction is released;

- if, after a certain time interval, the called subscriber answers, then the transmission of the reverse call tone and the calling signal is interrupted;

- afterwards, the connection between the two subscribers is initiated;

- after performig the connection, the subscribers start their conversation, and the system awaits for one of the subscriber B to hang up;

- after the conversation is finished (subscriber B hangs up) the connection between the subscribers is interrupted;

- the system returns to the initial status.

During this process, the calling subscriber cannot access any service of the low capacity exchange, while the called subscriber can only access the telephone services after the conversation starts.

VIII. THE MACRO-STATES GRAPH FOR THE PROCESS OF ESTABLISHING AN INCOMING TELEPHONE CONNECTION

In fig.4 is shown the macro-states graph for the process of establishing an incoming telephone connection in low capacity electronic telephone exchange.

Besides the macro-states M_0 - M_B defined in previous paragraph, a few more macro-states were defined as follows:

M_F - macro-state for monitoring the status of the junction line and for engaging it;

M_G - macro-state for transmitting an informational vocal message;

M_H - macro-state for awaiting the calling subscriber to transmit the DTMF selection information;

M_I - macro-state for receiving the DTMF selection information through the junction;

M_J - macro-state for awaiting the called subscriber to answer;

M_K - macro-state for conversation between the two subscribers;

M_L - macro-state for conversation between the duty subscriber or the operator and the calling subscriber;

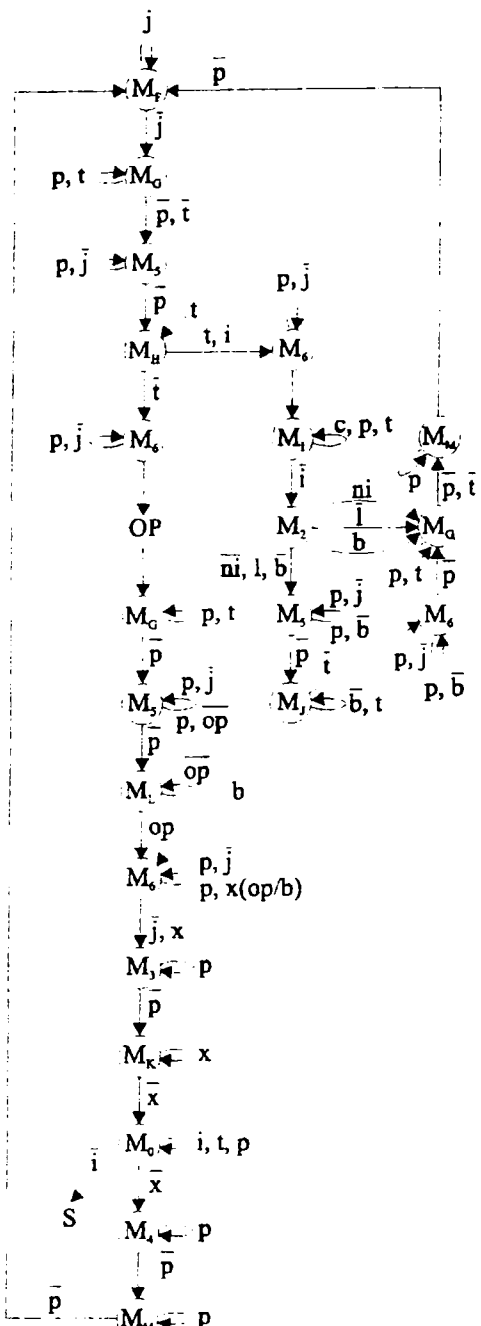M_M - macro-state for releasing the junction line.

Fig. 4.

The events are represented on the graph's arches and have the meanings mentioned in paragraph 4 with an additional one:

Op - the duty subscriber or the operator has picked up the phone.

Using the macro-states and the events defined above, the process of performing an incoming telephone connection can be followed on the graph.

IX. CONCLUSIONS

Based on the macro-state graphs that model the processes for setting telephone links (local, outgoing and incoming) and on the method of software implementation of multiprocess systems, the author

designed the command program of the main processor that controls a low capacity telephone exchange with temporal switching, using PCM encoding for the conversation signal.

There were also written the command programs of the peripheral processes for the individual subscriber circuits, the junction circuits, the temporal switching network and the tone machine.

The command programs, written in the assembly language of ATMEL family microcontrollers, require an amount of around 1-2 Kb of program memory for each peripheral process and of 8 Kb for the main process of setting telephone links.

The use of macro-states in the manner described above allows easily re-sequencing them for implementing also the telephone services.

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