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An Experimental Local PCM-Switching System

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Abstract—This paper discusses a local PCM switching network. The characteristics of this network are demonstrated with a model of three local exchanges.

All subscribers are connected with the exchange via concentrators. An exchange is controlled by a central processor with a stored program. This processor interacts with the peripheral switching units, represented by the central switching network and two types of control circuits, located within the exchange. These control circuits control either the concentrators or they communicate with counterparts, situated in other local exchanges.

All control functions that are not executed by programs of the central processor are realized by microprograms in a wired read-only storage (ROS) in these peripheral control circuits.

I. Introduction

In recent years many PCM-transmission systems have been installed in several countries. The main advantages of the PCM technique, i.e., low transmission loss and low noise, are, however, only achieved if not only transmission but also switching is carried out on a time division base.

These integrated PCM transmission and switching systems can be applied especially effectively in local switching systems. The reason is that the capacity of the existing local networks can be extended extremely by the multichannel use of each trunk.

Up to now, a lot of work has been done on PCM transmission problems but there exist only a small number of publications about local PCM-switching systems [1]–[8].

This paper describes an experimental local PCM-switching system. The development of this system has been done as a research project at the University of Stuttgart. Parts of the system, in particular hardware components, have been realized by students of the Electrical Department as student projects.

This research project was concerned with fundamental problems, such as configuration of concentrators, centralization–decentralization of the control units, realization of switching and control functions in hardware or software, and structure and control of the switching network regarding also aspects of traffic theory, coding, and decoding of analog signals. The interworking of this integrated PCM system with existing communications networks is up to now not considered in detail.

In the first concept, described here, only speech signals and data transmission in the speech band are considered. But investigations about the integration of data service and videotelephone are under way.

II. Structure of the Local PCM Network

The model of the local switching network considered consists of three exchanges. Each of them is connected with the two others (see Fig. 1) by two pairs of highways each. A highway has 30 speech channels according to the 30/32 channel PCM system [Conférence Européene des Administrations des Postes et des Télécommunications (CEPT)]. An exchange has a maximum of 16 concentrators and via each of them up to 512 subscribers can be connected.

The number of exchanges per local network is of course not restricted. The three exchanges in the model were chosen because this is the simplest network configuration that is able to handle all possible modes of traffic: internal traffic between two subscribers of the same exchange; external traffic between a subscriber of the considered exchange and a subscriber of a different exchange or a toll exchange; tandem traffic between subscribers of different exchanges (alternate routing).

The number of possible concentrators per exchange is also not restricted. 16 concentrators have been chosen to get a reasonable size of an exchange. The concentrator is connected with the exchange by one pair of highways (four wire connecting) with 30/32 channels.

The number of subscribers of a concentrator depends on the amount of traffic (originating and terminating). Admitting a probability of loss of 1%, about 20 erlangs may be carried on the 30 speech channels of the highway. If all subscribers have a small call rate a maximum of 512 subscribers can be connected to the concentrator.

III. Function and Control of the Concentrator

A. Description of the Block Diagram of the Concentrator (c)

The block diagram of the concentrator, including the subscriber sets, is depicted in Fig. 2. The subscriber sets are equipped with push-buttons, using a 2 × (1 of 4) - multifrequency code (MFC).

The subscriber circuit has a flipflop memory of two bits, indicating the following states:

- 00 Subscriber is idle.
- 10 Subscriber has just gone off-hook.
- 11 Subscriber is connected.
- 01 Subscriber has just hung up.

These memories are scanned and any change only of a subscriber state is transferred to the central exchange. This keeps the signal flow between concentrators and exchange very small.

The subscriber lines are concentrated by a four-stage link system (space division multiple) to 30 lines. This link system has its own marker for path-searching and switching of the crosspoints. Each crosspoint is controlled by a reset–set (RS)-flipflop as a holding memory, so that non-self-latching crosspoints can also be used. In the laboratory model first trials with an N-channel field-effect transistor (FET) were made.

The 30 outlets have a 2/4-wire terminating set each and are linked up to the multiplexer and demultiplexer, respectively, via low-pass filters.

The logic concept also allows the concentration by a time division multiple instead of the space division multiple.

In this case, however, the necessary number of 2/4-wire termination sets and low-pass filters (two per line) would be equal to the number of subscribers instead of 30 only.

Via one A/D converter and one D/A converter and a signal switching unit, the concentrator is connected with the highways to and from the exchange.

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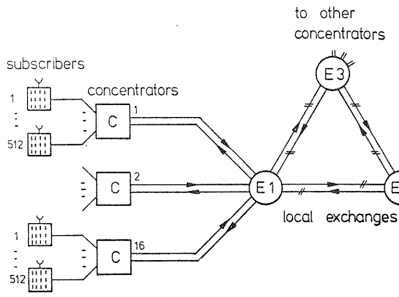

Fig. 1. Local PCM switching network.

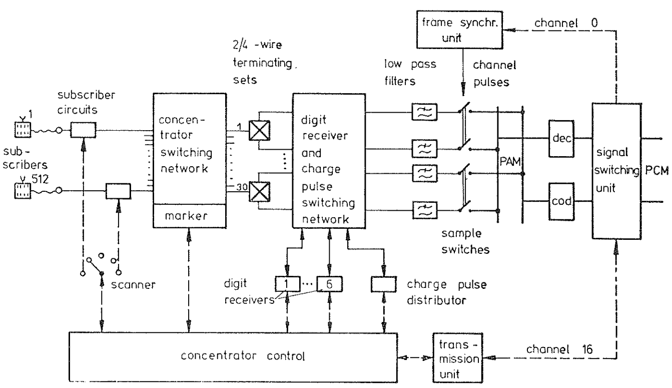

Fig. 2. Block diagram of the concentrator.

Six digit receivers are available to convert the dialed digits from MFC to binary signals. The inlets of these receivers are connected with the outlets of the concentrator switching network behind the 2/4-wire terminating sets.

As a special feature call-charge-pulses can be sent to the subscribers by means of a call-charge-pulse distributor. These pulses are received from the exchange as digital signals and are transferred to the subscribers as a 16-kc out-of-band signal.

In the signal switching unit the information of channel 0 (synchronization channel) and of channel 16 (bi-directional signaling channel) is switched to the frame synchronizing unit as well as to the transmission unit. The transmission unit receives instructions from the exchange or sends information from the concentrator to the exchange (requests for service or disconnection, digits, etc.).

B. Control of the Concentrator

The control of the concentrator is realized as a microprogrammed unit. The programs are stored in a magnetic read-only storage (ROS), having 1024 words, each with 12 bit.

A program run is initiated either by an instruction from the exchange or by an event within the concentrator.

The instructions from the exchange concern, e.g., switching in the concentrator network, connecting or disconnecting of a digit receiver, or transmission of call charges.

The events within the concentrator concern, e.g., a change of a subscriber state or a dialed digit.

To establish a connection, several microprogram runs are necessary. The main task of such a program is to transfer information from the transmission unit to registers and vice versa and to initiate switching procedures in the concentrator. Microprograms that are started by the exchange, send final information to the exchange whether they could be performed or not.

A microprogram run consists mainly of transport instructions, and therefore the set of microinstructions is very small (less than 10 instructions).

The microprograms for switching fill about half the ROS; the remaining part is provided for test programs.

IV. The Local PCM Exchange

Fig. 3 shows a block diagram of the exchange.

To each concentrator a so-called concentrator control circuit in the exchange (XCC) is assigned. The concentrator is connected with the central switching network (XSN) via the XCC. Similarly the other exchanges are linked to the XSN via an individual, so-called trunk control circuit (XTC).

A. Concentrator Control Circuit in the Exchange (XCC)

The XCC preprocesses the information from the concentrator. This philosophy of preprocessing forms a significant feature of the considered system.

The main tasks of the XCC concern the control of the connections and disconnections between subscribers and the exchange. The functions of the XCC are described by means of the following simplified example.

If a subscriber goes off-hook to request service, the scanner detects this subscriber, stops scanning, and initiates a microprogram in the concentrator control. The concentrator control transfers this information via the transmission unit to the XCC. The XCC hunts for an idle channel on the highway and, by means of a check-list, an idle digit receiver in the concentrator. If this was successful, the XCC sends an instruction to establish the connection between the subscriber line and the selected channel. The concentrator control announces to the XCC the success of this switching operation. Then the XCC sends the number of the selected digit receiver to the concentrator. After this connection of the digit receiver, the concentrator control confirms the performance. Now the XCC supplies the connected subscriber with dial tone and gives a message about the progress of the connection to the central processor. In a next step the dialed digits are handed over directly to the central processor (XCP), which controls henceforth the final steps of the call establishing.

If a subscriber in the concentrator is called, the XCC receives the necessary instructions from the XCP. By means of this information the XCC initiates the connection in the concentrator and the ringing tone, etc.

Besides these switching functions the XCC supervises the concentrator by order of the XCP.

The XCC was designed as a separate control unit in the exchange for the following three reasons.

1) The concentrator should be as simple as possible, i.e., the number of components within the concentrator has to be small. Then the power consumption decreases and the installation of the concentrator in the subscribers area and its maintenance will be facilitated. The more simplified the concentrator, the more complicated and time consuming the tasks of the XCP are. Therefore the XCC performs all functions that can be delegated to it without limiting the switching functions. Hence the load of the XCP can be kept in reasonable limits in order to use small computers. By this policy the costs for the stand-by central processor can also be reduced considerably. The reliability increases by decentralization.

2) As all XCC's are located in the exchange, one or two additional XCC's as a common stand-by are sufficient.

3) As most of the exchanges will be comparatively small (<5000 subscribers), the number of XCC's and XTC's can be economically adapted to the size of the exchange.

B. Trunk Control Circuit in the Exchange (XTC)

The XTC is the control unit for trunks (incoming or outgoing) to other exchanges. Compared with the XCC, the XTC is considerably less complicated.

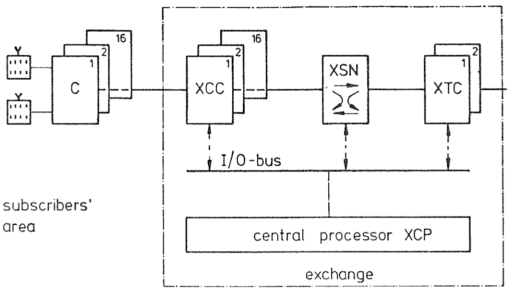

Fig. 3. Local PCM exchange.

The XTC receives switching information from the central processor and transfers them to the other exchanges and vice versa.

C. Central Switching Network in the Exchange (XSN)

The XSN connects the incoming highways from the concentrators and the other exchanges with the outgoing highways (Fig. 4).

The number of incoming and outgoing highways depends on the number of concentrators and the number of exchanges that are connected with the considered exchange. In the model 20 highways were chosen, 16 to the concentrators, four to the two other exchanges of the local network. Investigations have shown that for this configuration and prescribed traffic and probability of loss, a realization of the XSN due to suggestions of Walker and Duerdoth [9], [10] is a very economic solution.

This also holds true if the number of highways to the concentrators or to other exchanges is increased.

The principle of switching from a channel of an incoming highway to an idle channel of an outgoing highway via the XSN is the following.

At first a coincident switching is tried via the gates G_c. If this fails, a second attempt via the gates G_f and a fixed delay unit (FDU) is made. If this fails again, a third attempt via the gates G_y and a variable delay unit (VDU) is made. The number of these two types of delay units can be determined by means of traffic theory [11], [12].

The path-searching through the XSN is performed in the central processor by a program. Therefore the occupation states of all gates of the XSN are stored in the memory of the XCP.

D. Central Processor (XCP)

As has been shown in the previous sections, the main tasks of the XCP are: to control the XCC's and the XTC's; to interpret the dialed digits; to search for a path in the XSN and to establish internal and external connections; to initiate the supply of audible tones; to compute and store the call charge information; to maintain, supervise, and make error diagnostic of the whole system; to communicate with the maintenance or administrative personnel; to realize facilities such as different length of subscriber numbers, abbreviated dialing, automatic transfer, and realization of classes of service.

The program system of the central processor is divided into seven priority levels (Fig. 5).

Each interrupt level has its own organization program (ORG). The ORG schedules and controls the execution of the operating programs (OP) belonging to this level. The OP's are assigned to the different priority levels and can be executed only in the assigned level under the control of the ORG. These OP's perform the different tasks according to the signals from the peripheral units. Each ORG has access to a pool of auxiliary routines (AR), common to all ORG's. These AR's support the ORG in scheduling and controlling the OP's. The ORG's

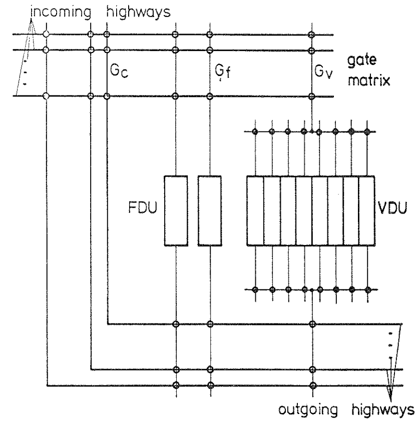

Fig. 4. Central switching network (XSN).

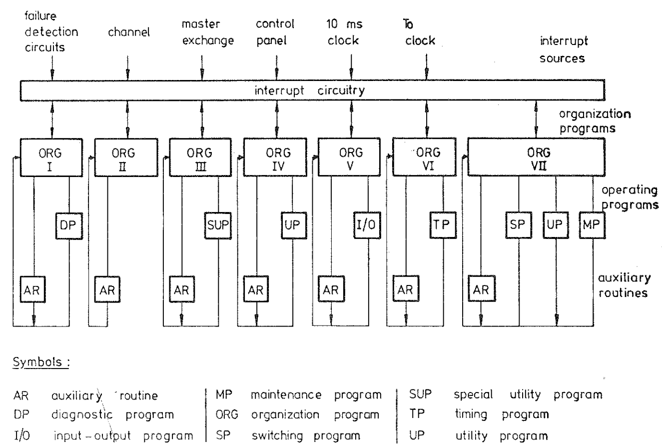

Fig. 5. Program control plan.

are initiated by the interrupt circuitry. The interrupt sources (such as failure detection circuits or clock generator) give signals to the interrupt circuitry and this unit transfers control to the ORG of the highest actual interrupt level. After finishing work in the higher priority level, control is given to the ORG of the interrupted priority class by the interrupt circuitry.

For the implementation of the system, a general purpose real-time computer is used as XCP. By means of this computer it is possible to gather experience, which can be a necessary base for the design of a special and more economic switching computer.

V. Facilities

The stored switching programs of the XCP enable the subscribers to activate all usual facilities. These facilities can be initiated either before dialing or during the established call. The activation of a facility during the call is done by pressing a special key of the pushbutton telephone.

VI. The Laboratory Model

The laboratory model that is being worked on at the moment will consist of one exchange with two concentrators. The function of the other concentrators and of the two other exchanges will be simulated within the XCP.

Up till now the first concentrator has been realized with its main functions such as subscribers scanning, switching to the highway, digit handling, and the information transport to and from the XCC.

The current work focuses upon the hardware and software components of the exchange.

VII. Comparison of the Considered System with other Known Systems

The system DEX-T1 of the NTT (Japan) and the system IFS-1 of the Swiss PTT, both local exchanges, show similar configurations.

The main difference from the considered system is that simple switching functions are carried out by the concentrator control circuit in the exchange (see Section IV. A). This policy diminishes remarkably the tasks to be performed by the central processor without any restriction on the flexibility of switching functions including the facilities.

The concentrator has been designed such that the information transfer between concentrator and exchange is kept as small as possible.

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