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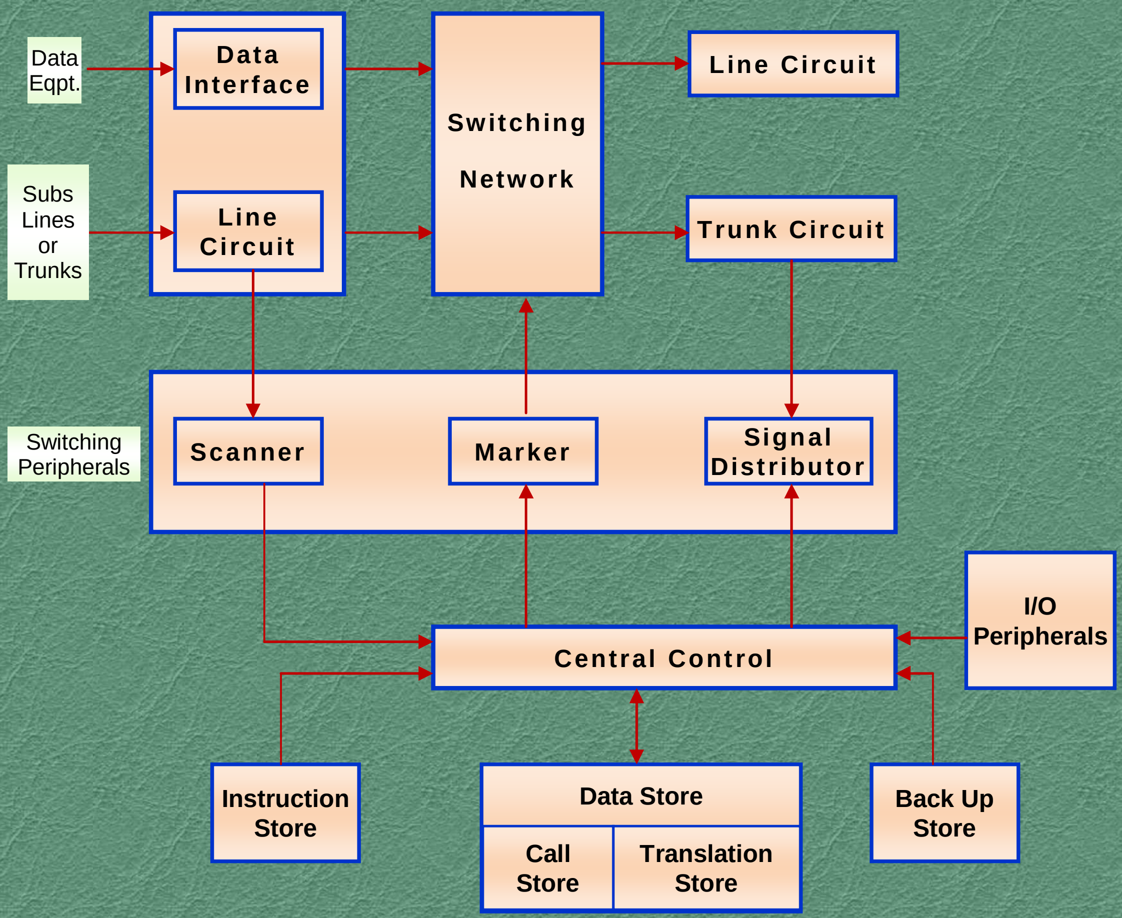
T 12D

BASIC PRINCIPLES OF SPC EXCHANGES



Indian Railways Institute of Signal Engineering and Telecommunications

SECUNDERABAD - 500 017

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BASIC PRINCIPLES OF SPC EXCHANGES

VISION:	TO MAKE IRISET AN INSTITUTE OF INTERNATIONAL REPUTE, SETTING ITS OWN STANDARDS AND BENCHMARKS
MISSION:	TO ENHANCE QUALITY AND INCREASE PRODUCTIVITY OF SIGNALLING & TELECOMMUNICATION PERSONNEL THROUGH TRAINING

INDIAN RAILWAYS INSTITUTE OF SIGNAL ENGINEERING & TELECOMMUNICATIONS
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BASIC PRINCIPLES OF SPC EXCHANGES

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CHAPTER 1

FUNCTIONS OF SPC EXCHANGES

1.1 Introduction:

In any Telephone Exchange, there are three functional areas, which can be identified as

1. Switching 2. Signaling 3. Controlling

1.1.1 Switching Function:

The switching functions are carried out through the switching network, which provides a temporary path for simultaneous bi-directional speech between:

- Two subscribers connected to the same exchange (Local Switching)
- Two subscribers connected to different exchanges (Trunk Switching)
- Pairs of trunks towards different exchanges (Transit Switching)

1.1.2 Signaling Function:

The Signaling function enables the various equipment in a network to communicate with each other in order to establish and supervise the calls. Subscriber line signaling enables the exchange to identify calling subscriber's line, extend dial tone, receive the dialed digits, extend ringing voltage to the called subscriber, extend ring back tone to the calling subscriber to indicate that called subscriber is being connected. In the event the called subscriber is busy, engage tone is sent to the calling subscriber. Inter exchange Signaling enables a call to be set up, supervised and cleared between exchanges.

1.1.3 Controlling Function:

The controlling function performs the task of processing the signaling information and controlling the operation of the switching network. Register Control Systems in multi exchange areas have the same routing number to a particular exchange from all other exchanges in the area.

1.2 SPC Exchange

1.2.1 Basics of SPC Exchanges:

Developed around 1965. Combines the art of computers with that of telephone switching, With the advent of the Integrated Circuits, use of programmed logic using an explicit program written in a Read Only Memory (ROM) was introduced. Changes required in services required rewriting the ROM with the new set of program Instructions.

The arrival of Microprocessors on the scene opened the door for stored program controlled systems. In these systems, the establishment and supervision of the connections in the exchange are under the control of Microprocessors, suitably programmed.

In SPC exchange, a processor is used to control the functions of the exchange. All the control functions and the associated logic can be represented by a series of program instructions. These instructions are stored in the memory of one or more processors, which control the operation of the exchange. Control is dissociated from the switching network and is centralized in a number of units on functional basis. Hence, the name Common Control Exchange arises for Electronic Exchanges.

1.2.2 Processor:

The processor of the exchange has to be shared by a large number of outside equipment such as subscriber lines, junctions, Trunks, etc., and the tasks related to the establishment and supervision of the various calls have to be performed 24 hours a day. It can, therefore, be said that the processor in the telephone exchange is a specialized computer.

The processor has the capacity to handle many thousands of instructions every second, say of the order of 5,00,000. The number of instructions necessary for the establishment and release of a call may be of the order of 8000 to 10,000. Hence in addition to controlling the switching function the same processor can handle other functions also.

1.2.3 Stores:

The processor contains program store and data Store.

Program Store contains all the instructions in their logical sequence used for the establishment of the calls, for other Operational, Administrative and Maintenance purposes.

Data Store includes Translation Store and Call Store.

Translation Store contains the details related to the configuration of the exchange, Viz., number of junctions, switch matrices, interconnection of these devices, data related to the subscriber and the services provided, details regarding class of service, routing etc.

Call Store contains the details of progress of the calls. Provides temporary storage for transient data required in processing the telephone calls such as digits dialed by the subscriber, busy/free conditions of the trunk/subscriber lines etc. The information in the call stores keeps on continuously changing with the origination and termination of calls. These details pertaining to each call are automatically erased when the call is disconnected.

Since all the relevant information is stored and the switching and other functions are carried out through program instructions, this type of switching is called Stored Program Controlled Switching. Both the contents of the Memory and the Instructions are easily modifiable which imparts great flexibility in the overall operation of the exchange.

1.2.4 Peripheral Devices:

Apart from the Central Processor, the Program and Data Stores, a number of peripheral equipment also forms part of the SPC exchange. This peripheral equipment allows the processor to communicate with the outside world. For example, scanners check the change of state of the subscriber equipment and junctions periodically. Distributors and Markers are used to convey orders sent by the processor to subscriber equipment and switching matrices.

The peripheral equipment is also needed to match the different speeds of operation of the processor, switching and signaling equipment. Peripheral equipment in the form of keyboards, visual display units, printers, etc., are required for Operational, Administrative and Maintenance purposes, to enable the maintenance personnel to give commands and receive information from the processor.

1.3 Functional Sub-divisions of a SPC Exchange:

The functional sub-divisions of a SPC exchange are illustrated in Fig.1.1 from which five main sub-systems can be identified.

1.3.1 Terminal Equipment:

- Terminal equipment on individual basis for each subscriber line and for inter exchange trunk.
- Switching Network, which can be space division or time division, unidirectional, or Bi -directional.
- Central Control consisting Microprocessor / Microprocessors and memories with a centralized or decentralized structure.

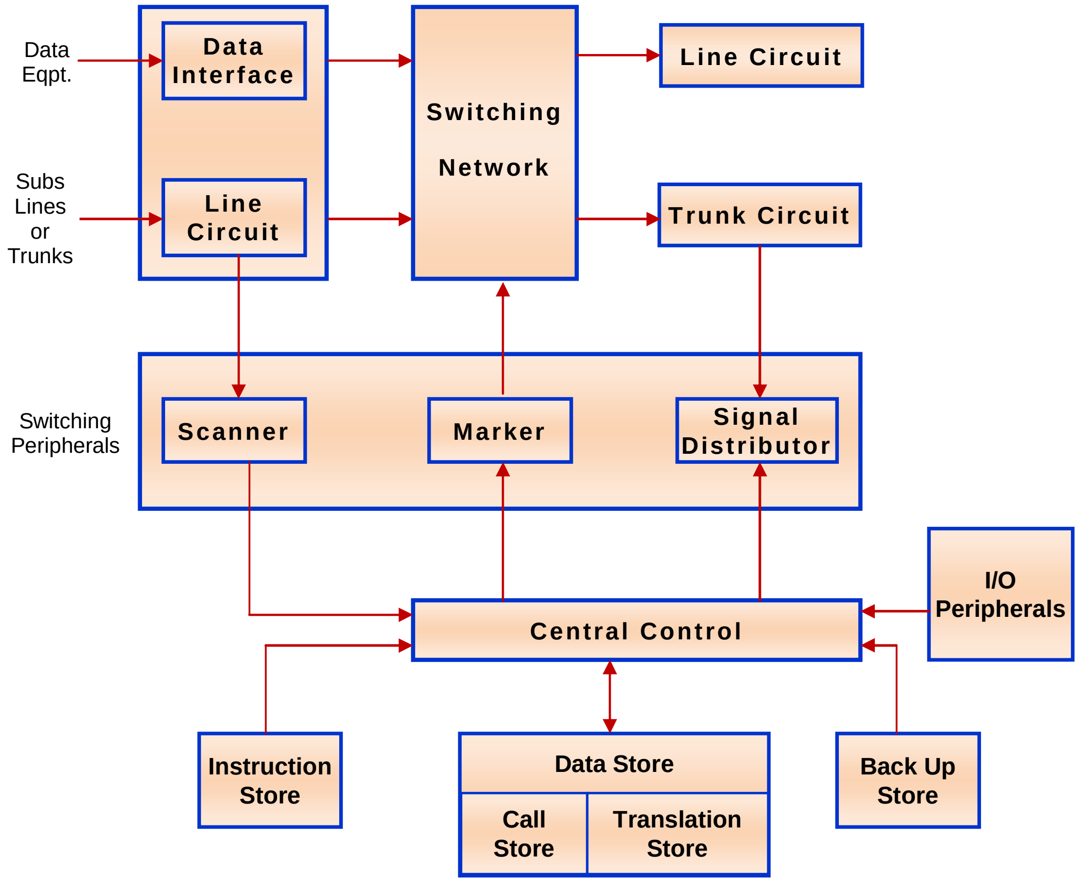


Fig. 1.1 The Functional Sub Division of SPC Exchange

- Switching Peripherals, viz, Scanner, Distributor, Marker and Interface circuits.
- Data processing peripherals (Tele typewriters, Visual Display Units, Printers, etc.) for Man - Machine Dialogue for operation and maintenance of the exchange.

The Line, Trunk and Service circuits are terminated with terminal equipment for status detection, signaling, speech transmission and supervision of calls. The line circuits carry out the traditional functions of providing battery feed to the subscriber and supervising subscriber lines. The trunk circuits are used on outgoing, incoming and transit calls, extend battery feed and supervise the calls. Service circuits perform specific functions like transmission and reception of dial pulses or multi frequency (MF) signals etc.

1.3.2 Switching Network: Digital Switching

The switching network sets up a temporary connection between two or more exchange terminations and ensures transmission of signals (speech & data) between these terminations in digital form with reliable accuracy. The digital signals, time division multiplexed basing on PCM principles, are received by digital switching network, on common media known as incoming PCM highways. The received signals are transmitted through the switching network to the outgoing PCM highways by digital switching as shown in fig 1.2. Switching network can be classified into

(i) Space Division and (ii) Time Division systems.

Space Switching: Same time slots of the incoming and outgoing PCM highways are interconnected. eg. Signals received in TS6 on I/C HWYS are transmitted in TS6 on O/G HWYS. Since the transfer of sample takes place in the same time slot, there is no delay in switching the sample. Different highways are interconnected. eg. Signals received on I/C HWY1 are transmitted on O/G HWY2 or 3 or any HWY.

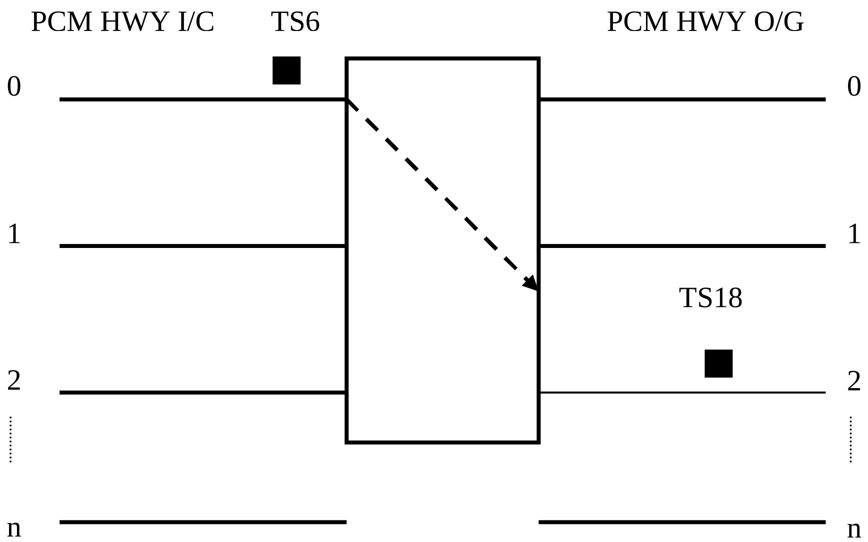


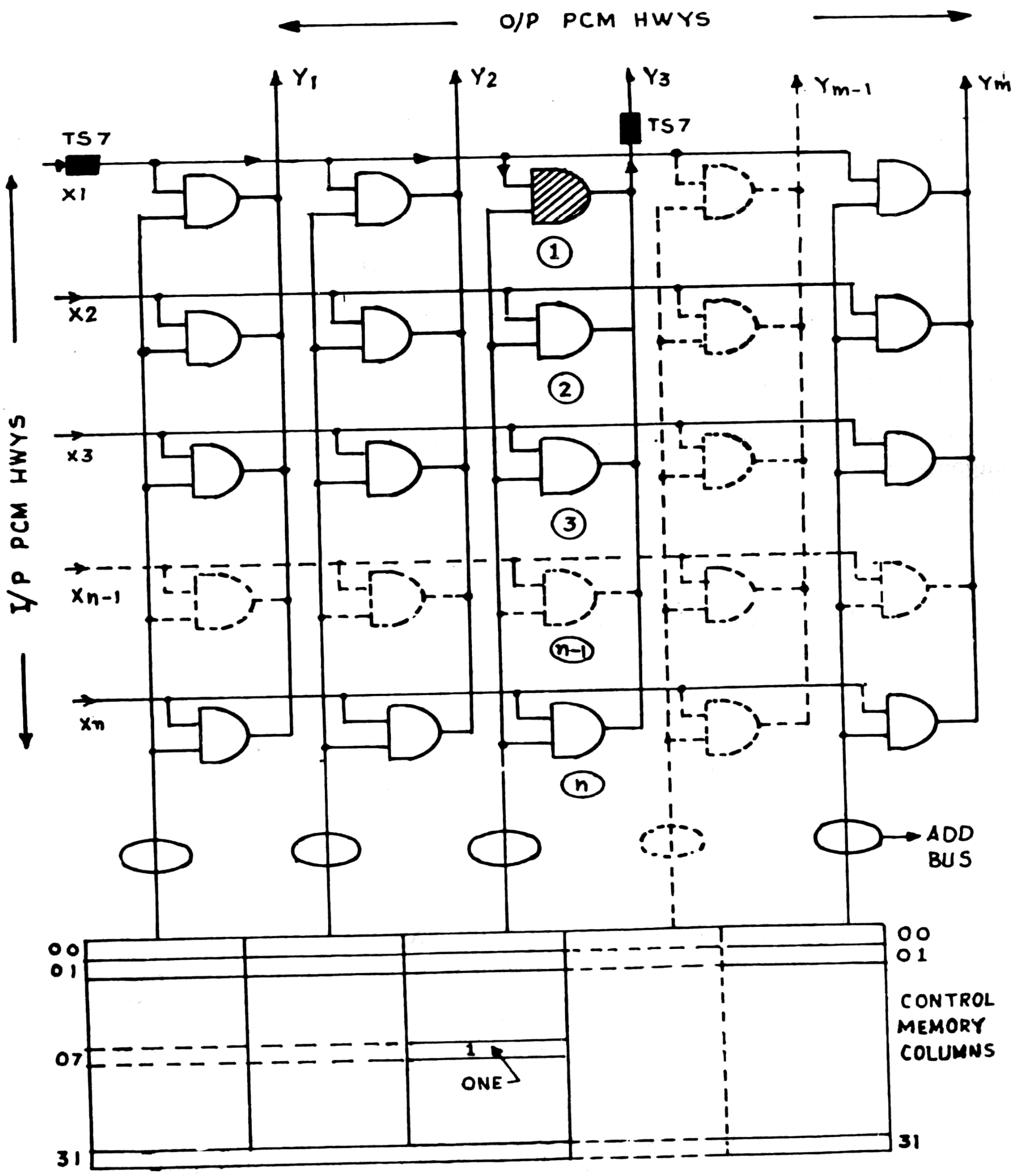
Fig. 1.2. Digital Switch

Digital Space Switch: (Ref. Fig.1.3): This switch consists of several input highways X1 X2 .... Xn and several output highways Y1, Y2 ….. Ym inter connected by a matrix of n rows and m columns. Individual cross point in this matrix consists of AND gate. Operation of an appropriate cross point connects a TDM channel of an incoming PCM high way to same channel of outgoing PCM highway during each time slot. During other time slots, same cross point may be used to connect other channels.

Each cross point column is connected to a column of control memory having number of locations equal to the number of time slots per frame in the PCM signal. Each cross point has a binary address, which is stored in the control memory

location in the order of time slots, so that only one cross point per column is closed during each time slot.

Fig. 1.3 Digital Space Switch



A new word is read from the control memory during each time slot in a cyclic order. Each word is read during its corresponding time slot, i.e., word 0 corresponding to TS 0 followed by Word 1 corresponding to TS 1 and so on. The word contents are held in vertical address memory location for the duration of the time slot. Thus the cross point corresponding to an address is operated during a particular time slot.

As shown in figure T12D.1.3, TS7 of HWY 1 is to be connected toTS7 of HWY Y3. The location corresponding to TS7 is 07. The address of I/C HWY is 01. The O/G HWY is Y3. The **address of I/C HWY 01** is written in **location 07** of **O/G HWY Y3.** During TS7 the central control reads the contents of 07 of HWY Y3 and enables the cross point corresponding to I/C HWY 01.The cross point remains operated for the duration of TS7 and the sample is transferred without any time delay. Central Control disables this cross point on completion of TS7, enables another cross point during TS8. The process repeats during TS7 of successive frames till the call lasts.

For disconnection of call, central control erases the contents of the memory location corresponding to TS7

Time switching: Different time slots of the incoming and outgoing PCM highways are interconnected. Eg. Signals received in TS6 on I/C HWYS are transmitted in TS18 or any other TS on O/G HWYS including TS6. Same highways only are interconnected. Eg. Signals received on I/C HWY0 are transmitted on O/G HWY0 only.

This involves time delay. A time switch is basically a time slot changer.

Digital Time Switch: The time switch consists of two memories.

- Speech memory
- Control memory

Speech Memory (SM): Known also as buffer memory. The received sample of an I/C HWY time slot is stored in a speech memory location till the destination time slot arrived. Speech memory has as many locations as the number of time slots in the input PCM i.e., 32 locations for 32 channel PCM system.

Control memory (CM): Known also as address or connection memory. control memory has same number of locations as speech memory. Each control memory location contains the address of one of the speech memory locations from where the sample is to be transmitted during the destination time slot in O/G HWY. The address is written in the control memory by the Central Control of the exchange,

A time slot counter counts the time slots from 0 to 31 and gets reset at the end and restarts. Time switch operates in two modes.

- Output associated control
- Input associated control.

Output Associated Control: (Fig.1.4)

The incoming samples are written sequentially in the speech memory locations.

eg. The sample received in TS4 is written location 04 of speech memory.

The locations of control memory are rigidly associated with the output PCM 's time slots. Each location contains the address of the corresponding time slot of the incoming PCM to be connected to.

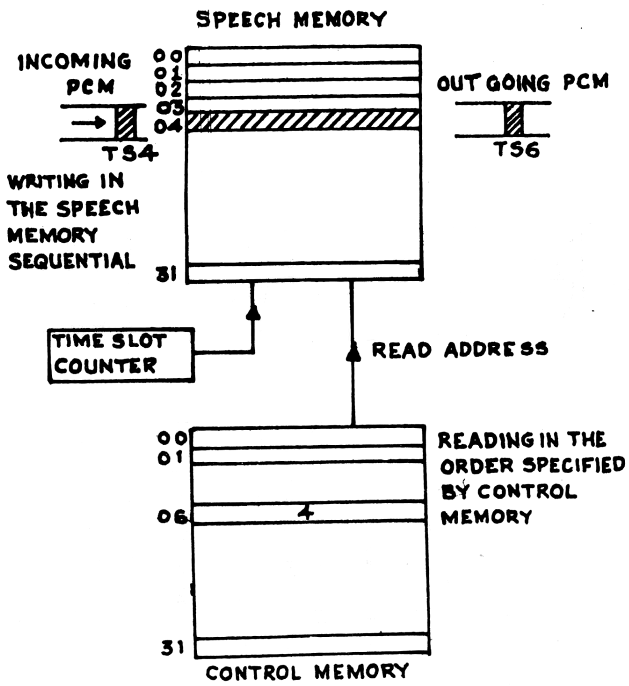


Fig. 1.4 Output Associated Control Time Switch

eg. The address 04 is written in the control memory location 06, which is associated with the O/G PCM time slot 06.

In this mode the 32 time slots in the incoming PCM are read at random and written sequentially by the control memory.

Input Associated Control: Fig.1.5

The control memory locations are rigidly associated with the input PCM's time slots and contain the addresses of the time slots of the outgoing PCM to be connected to.

eg. The sample is received in TS4 from the incoming PCM HWY, written in SM location 06 corresponding to outgoing PCM HWY time slot. The address of the SM location is written in CM location 04, which corresponds to time slot on incoming PCM HWY.

n this mode, the 32 time slots in the incoming PCM are written at random and read sequentially by the control memory.

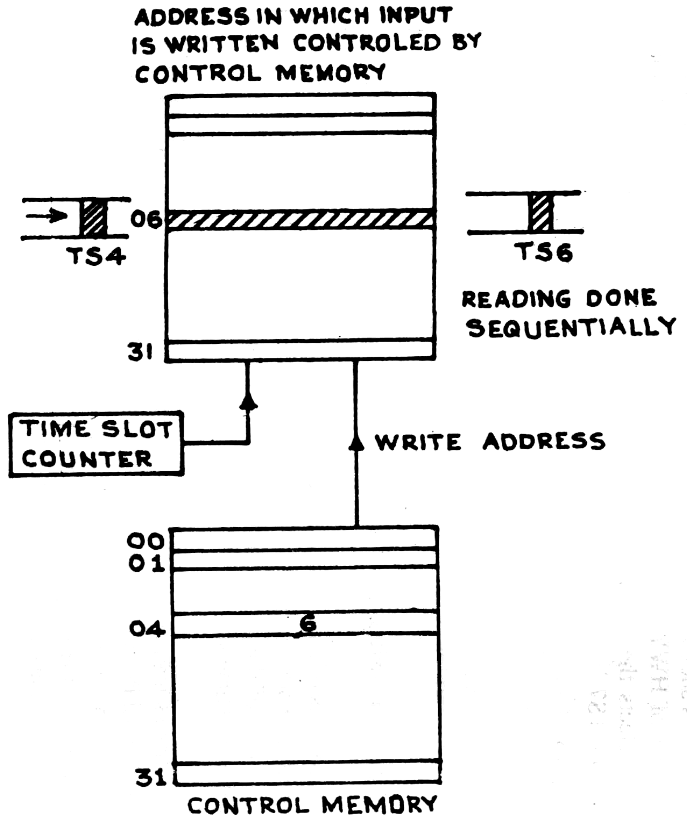


Fig.1.5 Input Associated Control Time Switch

Two Dimensional Switching:

As the size of the exchange increased, the space switch needs more rows & columns, and more cross points. The control memory columns also have to be increased. The time switch needs more SM & CM locations. This becomes prohibitive due to the higher cost of accessing and selection. Hence, the switching networks usually employ a combination of time and space switches.

The most commonly used architecture has 3 stage network i.e., STS or TST. Two-stage network TS or ST type is basically suitable for low capacity exchanges. However, TSST or TSSST or SSTSS may also be used.

STS type becomes unsuitable for high capacity network as the blocking depends only on the outer space stages. TST has less blocking probability because of non-blocking outer T stages and with smaller intermediate S stage. Either of the above two structures can handle up to about 20,000 erlang (Simultaneous calls in the peak Hrs.). It is unusual to have more stages i.e., STTS or TSST etc. More over, above 3 stages the path selection algorithms become more complicated.

TST network for a local exchange: Ref.fig.1.6.

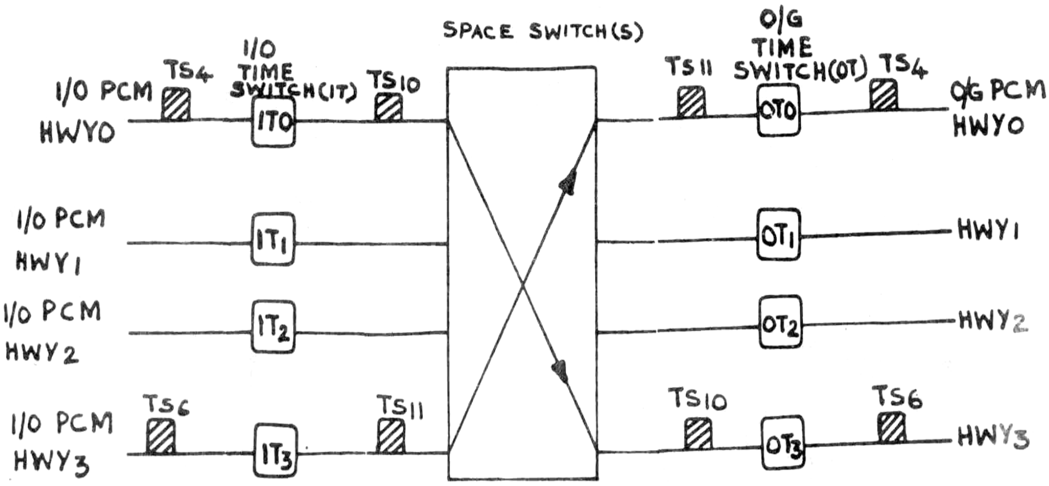


Fig.1.6 Typical TST Network For Local Exchanges.

The network consists of 4 nos. of I/C & O/G HWYs, one time switch each on every I/C & O/G HWY, IT 0 to IT 4 on I/C side and OT 0 to OT 4 on O/G side, one space switch with 4 X 4 matrix to inter connect HWYs. Central Control assigned TS4 on HWY0 to calling party and TS6 on HWY 3 to the called party. Speech samples of the calling party have to be carried to TS6 of O/G HWY 3 from TS4 on the I/C HWY 0. Similarly that of called party from TS6 on I/C HWY 3 to TS4 on O/G HWY 0. In space switch TS 10 from calling to called, TS 11 from called to calling are used as intermediate time slots for greater flexibility.

The 3 stages of switching: Refer fig.1.7

Calling to called:

- First stage: I/C HWY0 PCM sample received in TS4. Time Switch IT 0 time switches the sample to TS 10.
- Second stage: Space Switch space switches the sample from HWY0 to HWY3 during TS 10.
- Third stage: Time switch OT 3 time switches the sample from TS10 to TS 06.

Called to calling:

Similar process as above is carried out in reverse direction. TS11 is used in space switch.

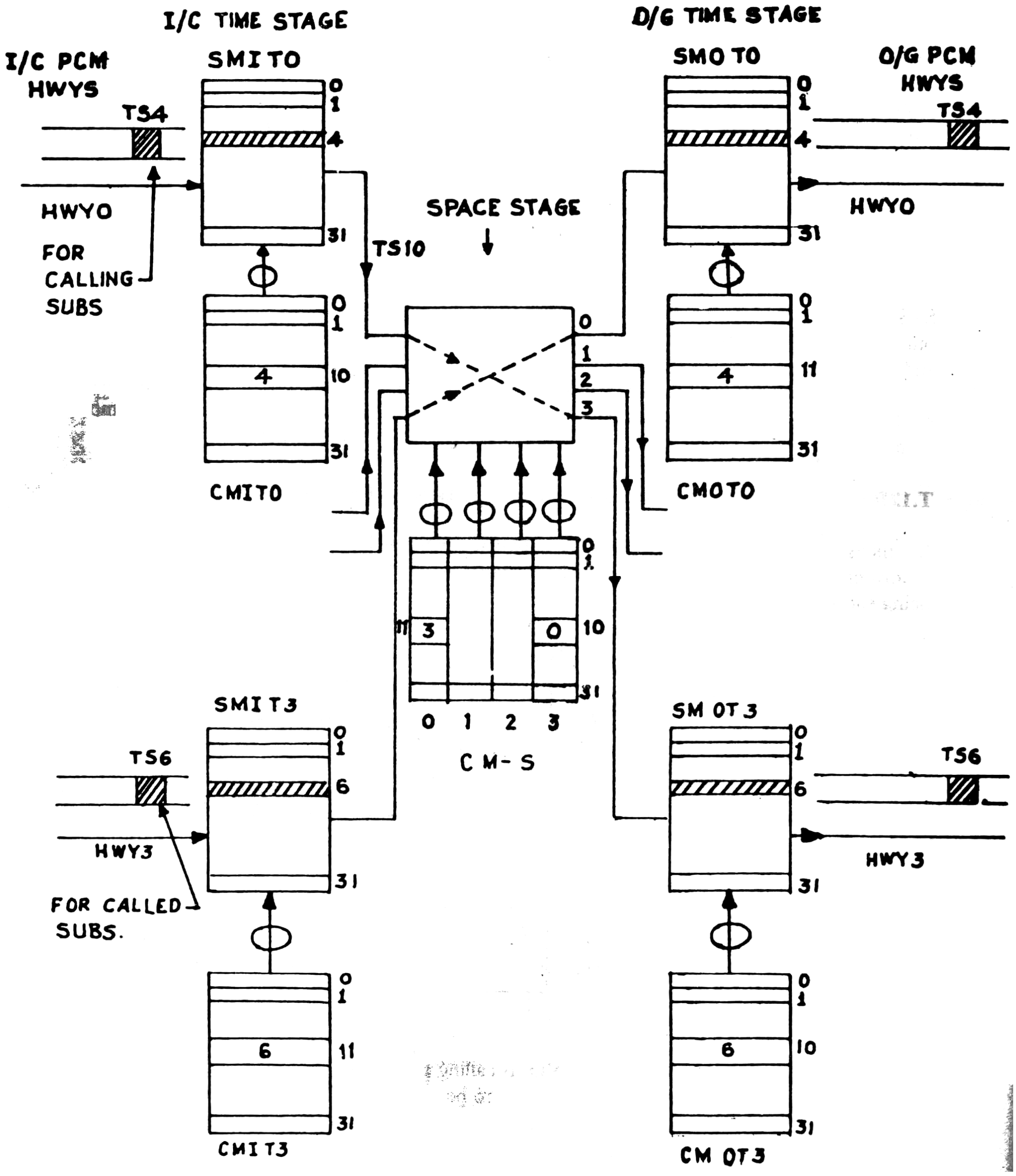


Fig.1.7 A typical TST Switch Structure

1.3.3 Switching Processor:

As mentioned earlier, the Switching Processor is a special purpose Real Time Computer, designed and optimized for the dedicated applications of processing telephone calls. Events like subscriber lifting the handset, replacing the handset at the end of the conversation, reception of dialed digits etc., will have to be processed at the time of occurrence and cannot be deferred. The Central Control is a high speed-processing unit controlling the operation of the Switching Network, capable of executing about 5,00,000 or more instructions at a time. It contains three stores, viz., program store, translation store and call store. The translation store and call store together are normally referred as data store.

1.3.4 Switching Peripheral Equipment:

The Switching Peripherals are the intermediate stages between Switching Network & Terminations and the Central Control. All functions associated with Call Processing, such as establishment and release of a call, can be done by the Central Control through various programs. The processor must also perform many other tasks such as administration, maintenance diagnostic etc. To carry out all these functions, the processor must be very powerful & the volume and complexity of software increases. Hence, in practice, the switching networks and terminations are not directly controlled by the Central Control These functions are performed by the Switching Peripherals.

Orders for switching functions are passed from the Central Control to the switching peripherals, which decode the orders and carry out the desired functions independently, without any further involvement of the Central Control. Thus precious time is saved for the central processor. The different functions performed by the switching peripherals under the instructions of the Central Control are

- **Scanning** the subscriber lines to identify the status of subscriber.
- **Marking** to drive the switching networks to establish or to release a call.
- **Distributing** the control signals to subscriber lines and trunks.

These three functions are performed by three main switching peripherals - Scanner, Marker and Distributor respectively.

Scanner: Detects and informs the central control of all significant events on the subscriber lines and trunks connected to the exchange. The signals received from these devices may be continuous or discrete. The scanning rates for the various devices in view of their diversity also vary. For example, on a subscriber line with decadic pulse signaling with a Make to Break ratio of 1:2, the necessary precision required is of the order of 100 milliseconds for pulse detection while other continuous signals such as clear, off-hook etc., on the same line are usually several hundred milliseconds. The scanner stores the data in the corresponding memory. The Central Control during its routine functions, periodically reads this data, performs decision-making function and communicates to other switching peripherals for execution of the orders.

Each subscriber's line circuit has an individual opto isolator, which remains normally in OFF State (Fig.1.8). +5V, which is considered as level ‘1', is fed to the input of IC 74LS244 after double inversion. The subscriber line interface card (SLIC) has 8 line circuits and 8 different status lines come as input to the octal bus driver 74LS244. Whenever any subscriber lifts handset, r his opto isolator operates and status line changes from 'I' to ‘0’. When bus driver is enabled, by the pulse from processor, information of 8 status lines is fed to the signal processor simultaneously. Thus scanning or testing is done. By sequentially enabling different bus driver ICs of different SLIC cards, processor can continue scanning of all lines. The results of these scanning i.e., the 8 bit status information (one bit for each line) is recorded or stored in scanner memory.

Marker: As the operating speed of Switching Network is very slow in comparison with that of the processor, the switching is controlled by an intermediate stage called Marker. In Space Division Switching, it operates the cross-points. It physically sets up and releases the paths through the switching network, under the control of the central processor and path is operated only when it has been recorded in the Central Processor Memory. Similarly, paths are released when cleared in the memory. If Time Division Switching is used, the marker writes the information in the control memory of time and space storage and the response time of the marker is quite high of the order of tens of milliseconds.

In digital switching, speech is switched in TDM-PCM. The conversion of analog to digital speech is done by the CODECs, which are used one per line. Each line is to be switched once per 125 microseconds as per sampling theorem. This is done in practice by enabling the required CODEC once per 125 microseconds. With the CODEC enabled, the digital speech passes to the corresponding location of the information memory and gets stored there. In receive direction, the stored digital speech is fetched from information memory of corresponding location and is fed to the line circuit via CODEC. In digital switching, time slots are allotted to each line circuit. The processor decides the CODEC that is to be switched during a particular time slot and enabling of CODEC is done by the Marker.

Distributor: It is a buffer between the **High Speed Low Power Control Processor and the Slow Speed-High Power Signaling Terminal Circuits**. It is the interface between subscriber lines / trunks and central control for distributing various signals on subscriber lines / junctions. It operates relays (at higher power level) in subscriber line circuits by converting orders received from processor for distribution of signals.

Each line circuit has its own ring and test relays. Signal from Central Control comes to the SLIC, where it enables the particular transistor and relay of the termination. 8 signals come at SLIC and are passed to individual relays through a bus driver IC 74 LS244, after the IC is enabled by processor.

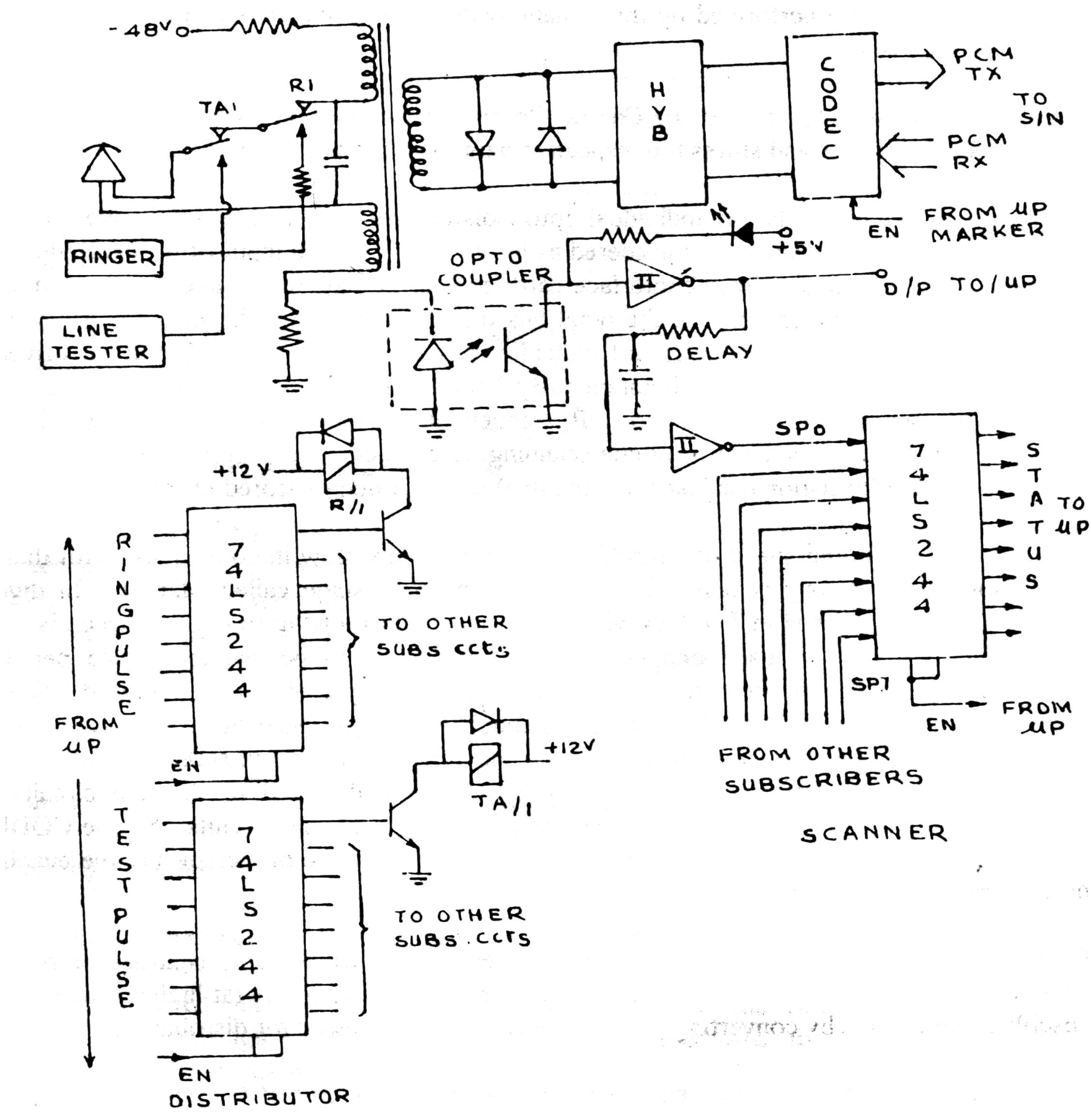


Fig.1.8 Subscriber Line Interface

Distributor transmits various signals to subscriber and other exchanges. The signals to be transmitted over the lines and trunks differ significantly in terms of time constraints. Inter exchange signal pulses, for example, must be relatively accurately timed, whereas a certain delay is acceptable for transmission of a tone or ringing current to a subscriber line. Speed of distributor depends upon the application.

1.3.5 Interface Circuits: Each command from the processor has a code consisting of the address of the particular peripheral to be operated. This address is first decoded in an interface circuit, which guides the command to a particular peripheral that has been addressed.(Fig.1.9)

Line Interface Circuit: To enable the SPC exchange to function with the existing outdoor telephone network, the subscriber's line interface is used. The functions of the SLIC (Subscriber's Line Interface Card) is commonly referred to as BORSCHT function, the Acronym signifying.

B Battery Feed
O Over Load Protection
R Ringing Voltage
S Supervision of Subscriber's Loop Status.
C Coding
H Hybrid
T Testing

these functions cannot be performed directly by the electronic circuitry used in the SPC exchange and therefore suitable interfaces are required.

Transmission Interfaces: Transmission interface between the analogue trunks and digital trunks (individual or multiplexed) such as A/D and D/A converters are known as CODECS. These can be provided one per a line/trunk basis or on the basis of one per 30 speech channels.

Signaling Interfaces: Two are more exchanges are connected through signal interfaces. A typical telephone network may have various exchange systems each having different signaling schemes. In pulse signaling the digit dialed is sent in the form of pulses of 100 millisecond each out of which 66.7 millisecond is break pulse & 33.3 millisecond is make pulse. In DTMF signaling each digit is transmitted as a combination of 2 out of 7 frequencies. In both the pulse signaling and frequency signaling, the signals are sent over a channel directly associated with the speech transmission circuit for that call. This type of signaling is called **Channel Associated Signaling**

Recently, however, common channel signaling in which the signaling is separated from the speech transmission network is evolved. A separate signaling network carries the signaling information of several channels between two exchanges.

Normally **SPC exchanges use Common Channel Signaling to Specification ITU(T)'s No CCS 7.** The common channel signaling links are again connected to the central processor through the common channel signaling terminal.

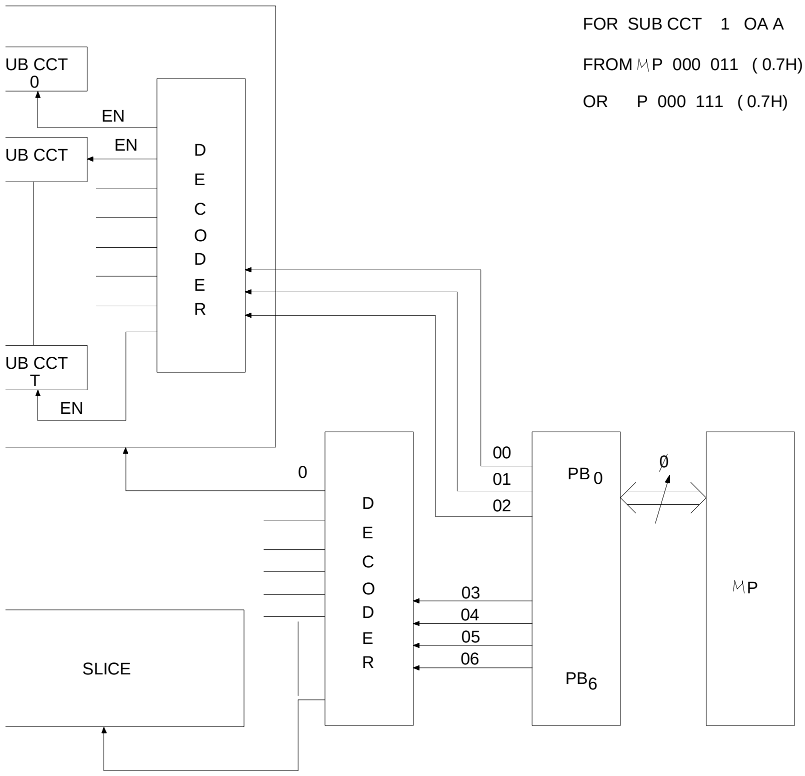


Fig : 1.9 Enabling Peripheral by Data From Microprocessor

1.3.6 BUS System:

The switching peripherals are connected to the central processor by means of a common bus. A bus is a group of wires on which data and command pulses are transmitted within the various sub-units of a switching processor or between switching processor and switching peripherals. The common bus system avoids costly interconnections of the various equipments.

1.3.7 Data Processing Peripheral:

Man-Machine Dialogue terminals such as key boards, visual display units (VDU), printers, etc. are used by Operator to enter the commands for Administration and Maintenance purposes.

Data Structure:

In SPC exchange, a lot of data has to be stored in the data stores. The data is classified as

- **Permanent data:** Hardly ever changed during the lifetime of the SPC exchange.
- **Semi permanent data:** Changed depending upon the traffic distribution, changes in subscriber's class of service etc.
- **Variable data:** Call set up information, which loses its meaning once the particular connection, is established or cleared.

  Faults in variable data affect only the calls just being established, while faults in the other two categories of data affect all the calls that use this information. It is, therefore, necessary to store the permanent and semi-permanent data in protected area of the data store. Data can also be classified as

- **System Data**: Depends upon the design of the exchange and have to be present in all the exchanges. They are fixed tables that are not altered and therefore, are only **read-out** as and when required.

- **Exchange Data**: Pertains to all the data concerning the exchange such as, details of the switching network, terminals, trunk equipment, peripheral devices, etc. The volume of the exchange data is approximately proportionate to the size of the exchange.

- **Subscriber Data**: Each subscriber is permanently assigned storage space for basic data such as telephone number, line categories, classes of services etc. The volume of subscriber data increases with the number of subscribers.

1.3.8 Establishment of a Local Call:

Having gone through the basic principles of the SPC exchange, let us consider the establishment of a local call.

The line-scanning program scans the subscriber's lines continuously and when a subscriber lifts the handset, this **event (off-hook)** is sensed by the operation of the relay contact of the appropriate line relay. In order to confirm that the off hook condition was not observed earlier, the central control compares this with the result of the previous scanning cycle and concludes that a request for connection has occurred and updates the status information for that particular line as **busy.**

From the scanner address of the calling subscriber, the central control refers to the details about the subscriber, stored in the translation stores. The central control then selects an idle digit receiver and establishes a free path between the calling subscriber and the digit receiver, through the mark and drive program. The identities of the originating Junction circuit and the digit receiver are stored in the register-buffer.

The central control instructs the signal distributor to operate a relay in the digit receiver to send dial tone to the calling subscriber. Digit receiver returns dial tone to the calling subscriber. The digit receiver is only capable of detecting the dial pulses, but cannot count them. As soon as the first digit pulse is received, dial tone is cut off.

The calling line is scanned at every 10 milliseconds through another scanner to detect changes in the line conditions due to dial pulses. The central control compares the present scanner reading with the previous one, Whenever change is noticed and the line is **off- hook,** the central control adds one to a pulse count kept in the data stores of the particular line. When no change is detected for a period of at least 100 milliseconds, it is interpreted as an Inter digital pause. When the last digit has been received, the dialed number is converted to a translation store address, where it finds the corresponding translation information of the called line, which includes the called line's scanner address and other details such as class of service, category, etc. The system now checks if the called line is busy or free by looking at its **busy-idle bit.**

If the called line is free, the digit receiver is released from the calling line, the central control now searches in the data store for a path to be used to establish conversation between the calling and called subscriber, through the mark and drive program. When a free path is selected, the identity of the selected terminating junction is stored, the path established and ringing phase started. Central control instructs the signal distributor to apply ringing current on the called line. When the called subscriber responds, ringing is tripped and speech path is established between the calling and called subscribers.

The system now scans both sides at every 100 milliseconds for a possible disconnection, after which the lines are restored to normal. Further, normal scanning to detect origination of new calls is continued.

1.4. Advantages and Disadvantages of the SPC exchanges:

Less switching accommodation.

- Less maintenance effort.
- Faster installation.
- Ease and flexibility in modifying new services and features.
- Components used have no conventional wear and tear

Air-Conditioning: Since the control is through a Microprocessor based Control Processor with the Auxiliary Memory etc., the need for Air-conditioning is more stringent.

1.4.1. Facilities;

To Subscribers: The most important advantage of an SPC exchange is directly derived from the use of stored program. The program and data can easily be modified and, therefore, improvements and changes in the operation can easily be introduced in a working exchange without the need for elaborate hardware changes nor there is any need for making large variations in wiring. Apart from this some more services are:

- Abbreviated Dialing.
- Priority Calls
- Conference amongst several parties in-group.
- Call Waiting
- Call Forwarding
- Call Transfer
- Camp on Busy, etc.

To Administration: Many administrative functions such as allocation of new directory number to a subscriber and determining his class of service etc. can be done through software only without need for any wiring changes. Modification of routing table, traffic analysis etc., can also be carried out without difficulty,

To Maintenance:

This is one of the most important advantages of SPC switching. This is partly due to improved reliability of the components used and partly as a result of the nature of SPC exchange.

Special facilities included in the program of the processor are able to detect and locate faulty units. Diagnostics program is always included in the SPC exchanges. Defense or pre-emptive programs allow the processor to detect a faulty unit in the exchange and disconnect it from serving traffic. Integrated automatic testing of subscriber lines, Inter-exchanges trunks etc. can easily be carried out.

- Automatic billing
- Centralized supervision & Maintenance
- Automatic load control
- Traffic recording and analysis are possible
- Automatic program testing & Diagnosis

Objective:

1. Switching, signaling and controlling are the 3 main function of SPC exchange. (T/F)
2. Switching provides bidirectional speech path between two subscribers. (T/F)
3. Loop signaling enables the subscriber to get connected to the exchange. (T/F)
4. Monitoring of the call process is done by controlling function. (T/F)
5. Program store contains the instructions to establish the call among various subscribers. (T/F)
6. Call store contains the details of call process and progress. (T/F)
7. Call stores are temporary stores. (T/F)
8. Terminal equipment contains line cards and trunk cards. (T/F)
9. Digital time switch consists of two memories such as speech memory and control memory. (T/F)
10. TST stands for Time Space Time switch. (T/F)
11. Scanner detects the status of the subscriber. (T/F)
12. Distribution of signals to subscriber and trunk is done by distributor. (T/F)
13. BORSCHT function is performed by control cards in exchange. (T/F)
14. SPC exchanges utilize common channel signaling. (T/F)
15. Exchange data contains hardware configuration of exchange. (T/F)
16. Class of service is part of subscriber data. (T/F)

Subjective:

1. Write short note on switching, signaling and controlling.
2. Describe in short the functional sub division of SPC exchange
3. What do you mean by a switch? How many types of switches are available?
4. Write in short the function of scanner, marker and distributor.
5. Describe line interface card.
6. What are the facilities available in SPC exchange?

CHAPTER 2

COMPUTER SOFTWARE FOR ELECTRONIC EXCHANGES

2.1. Introduction:

The basic purpose of a telephone exchange is to set up and release telephone calls. In electronic SPC exchanges these jobs are done by software, which can be divided into

- Operating system software (OS)
- Application program software

2.1.1 Operating System Software (OS): Takes only 20% of the software volume and enables the resources of hardware to be utilized effectively. It enables terminals and disc drives. OS can be classified as on line and off line.

- **On Line OS:** Only a small part of operating system resides **on line** due to limitation of on-line space and also because full operating system is not used always. Scheduler, Device Handler are examples of on line operating system.
- **Off line OS:** This is large in size and is brought on line only when required, examples are assembler, compiler, debugger, file transfer, Library, etc.

  Operating system software is also classified as Batch processing, Time Sharing and Real time. The last one is used in telephone exchanges.

2.1.2 Application Program software: About 50% is used for maintenance program, 20% for call processing program and the rest 30% for administrative program. Call processing program takes major part of the processor time though constitutes only about 20% of total instructions. A typical exchange contains about 3 to 5 lakh instructions. Importance and size of Administration and Maintenance functions are growing day by day as the exchanges are becoming more sophisticated.

2.1.3 Real Time Processing: Electronic exchanges have several **Real Time processing** stages, each differing in terms of time constraints. The most strict real time constraint concerns signaling and signal processing. For the entire portion of call processing, it is possible to process a signaling event just for 10 ms. To achieve real time operations, a multi-level interrupt mechanism is provided. Whenever a particular interrupt is generated, program sequence control is transferred to the corresponding interrupt level program. Maintenance program is subdivided into fault recognition, diagnostic and test programs. Fault recognition programs are executed on demand by interrupts operating at higher levels causing the system to give priority for execution. This ensures timely identification of faulty unit for system recovery. Diagnostic program localizes a fault in a unit and is executed as and when requested by fault recognition or test programs.

2.1.4 Call Processing Programs: These programs are further divided into **input, output and call control programs**. Call origination, digit collection, detection of flash in and established call are done by input programs and are high priority ones. Operation of cross points in the switching networks (for analog exchanges), memory manipulation, feeding of tones, out pulsing of digits in the terminals are done by output programs and they are also high priority ones. Call control programs analyze, process the inputs and results are handed over to output programs for carrying out to appropriate sections. These are low priority programs and form the bulk of call processing software.

2.2. Software for SPC Exchanges:

The software of the electronic switching system may be classified from different angles depending on where and when it is used. The programs are mainly classified as on-line and off-line programs. On line programs are used by the exchange in working condition, for telephone service and maintenance. Off line programs are not needed for normal telephone working. These programs are needed for the Administrative functions & diagnostic operations. Off-line programs can be fed into the working exchange during idle time of on - line programs.

The on-line programs can further be divided into two groups resident and non-resident. Resident programs are located in the main memory while the later are stored in auxiliary memory systems and on demand transferred to the main memory. The resident programs are -operating system, call processing system, malfunction detection and handling system and some administrative programs. The typical non-resident programs are most administrative programs and fault diagnosis programs.

The establishment, disconnection and control of speech path between a calling and called line is the factor of line constraint. It means that the exchange must work under real line conditions. Real time processing is made possible by the concepts of interrupt, event and queue.

Call processing programs are grouped in various levels of interrupts in such a way that a program from a higher interrupt level is allowed to interrupt the execution of a program of lower levels. There are three basic types of interrupt levels - fault detection level, clock level and base level. When a fault is detected, the processor starts maintenance program. Call processing programs may lie in clock or base level, while most of the administrative programs lie in base level. When an interrupt occurs, execution of the current program is stopped and the register contents are saved. The interruption program is then executed and the original interrupted program is executed after the register contents are restored.

When any change in state occurs externally to the exchange e.g., subscriber off-hook, dialing are called events. CPU collects events from external world as inputs, then analyzes these events by internal processing and instructs the hardware or/ and software about the actions to be taken. The input and output are subject to hardware operation speed and time constraint external to exchange while the internal processing needs less time scheduling but more instruction steps.

The concept of queuing accommodates the different requirements of detection and treatment of events. An event after its detection is immediately analyzed and put into an appropriate queue according to the task. The queue is a buffer in which events are stacked in the order they arrive. When the turn comes for the treatment of events, a task processing program takes an event out of queue on **first in first out basis**, performs the appropriate logical functions on it and puts the result in another queue.

The basic parts of a call processing program as in Fig.2.1 are scheduler program, scanning program, mismatch treatment program, call treatment program, mark and driver program, permanent data tables, semi-permanent data tables, register buffers and status buffers, queues and order lists.

2.2.1 Scheduler:

As a processor, handles all programs in a proper sequence, the scheduler initiates the various programs at the appropriate time depending on the necessary frequency of their execution. It is a central part of the operating system and controls the execution of other programs. After a program is executed, the control passes back to the scheduler.

2.2.2 Scanning Program:

The status of several test points in line or trunk circuits is interrogated simultaneously at regular intervals. CPU compares the interrogation results with the previous status, stored in the memory of the same test points. The comparison indicates which test points have changed status since the last scanning.

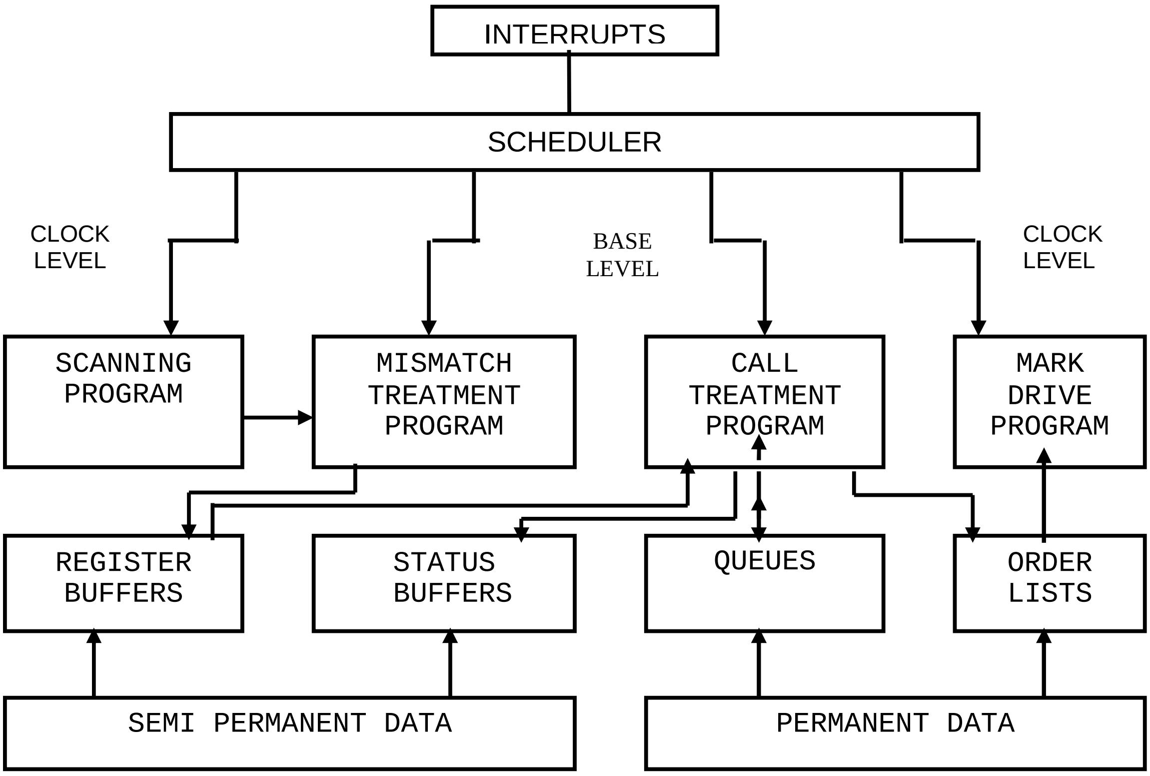


Fig.2.1 Basic Parts of a Call Processing Program

2.2.3 Mismatch Treatment Program:

Interprets the meaning of new events according to the state of the calls and the result is put in a queue or a buffer for an appropriate call treatment program.

2.2.4 Call Treatment Program:

A series of functional program modules are used in this package during the establishment and control of a call. The important among them are path search program, prefix analysis program and charging program. The path search program is used to find a free path between a determined inlet and determined outlet. The path search program structure depends on the network architecture. In SPC systems, one path search principle based on hardware interrogation by means of network testers and one based on software interrogation by means of map-in-memory technique are employed. The prefix analysis program produces routing and call charging information depending on the prefix of the dialed number, by using the prefix analysis table. Charging program ensures proper charging of subscriber calls.

2.2.5 Mark and Drive Programs:

After call treatment, actions to be taken by hardware are determined. These programs send orders to the speech path equipment via peripherals.

2.2.6 Data Table:

The permanent data tables form part of the system logic, while the semi-permanent tables contain information of exchange hardware, prefix analysis tables, subscriber data tables. Every subscriber has his own individual information stored. The information covers the correspondence between the directory number and equipment terminal number to which the subscriber's line is connected, subscriber line categories and special facilities to which the subscriber is entitled.

2.2.7 Buffers:

A register buffer that is also called **call store** is associated with each new call, from the detection of **off-hook event, to the ringing phase and to disconnection of call**. This register stores all relevant information connected with the call in progress. A status buffer is associated with each trunk circuit and stores the information on the call status.

2.3. Establishment of a Local Call:

The following sequence explains the establishment of a local call in an SPC exchange. There may be variations in the design of a particular system. Nevertheless in essence the sequences are more or less similar.

2.3.1 Calling line scanning. Pre selection & connections

A line-scanning program, in clock level, checks the lines every 10 ms If an off-hook event is detected for a subscriber, the equipment terminal number (hardware) identity is written in a queue. Then mismatch treatment program, in base level, seizes a free register buffer and after finding the identity of the calling subscriber and reading its line category (class of service), stores the information in the register buffer.

The path search program finds a free path between the calling line and a dial pulse receiver. The path searching results are then handed over to a marker and driver program. The later is in clock level and sends dial tone to the calling subscriber. Please refer fig.2.2

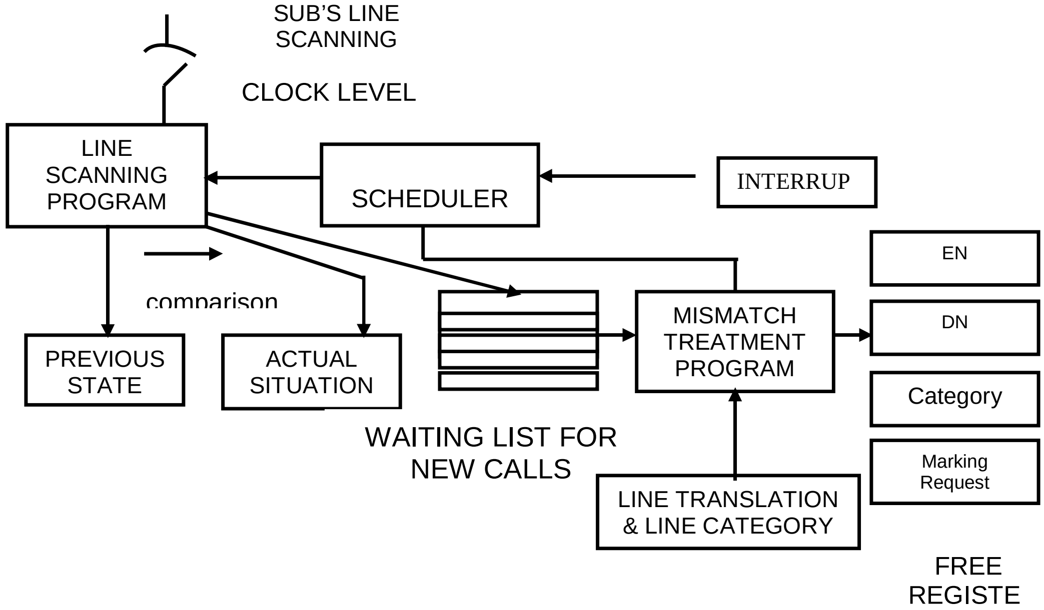


Fig.2.2 Line Scanning And Register Seizure

2.3.2 Digit Reception and Prefix Analysis: Fig.2.3

When a dialed digit is received at the exchange, the dial pulses are detected by a mis-match scanning program in clock level. The pulses are counted, stored in the register buffer. When a prefixed number of digits are received, the prefix analysis program is executed and the details of the call are stored in the register buffer. After all the digits are received, a program which handles local call establishment, checks the called subscriber's equipment number and line category. Then the equipment number and register address are stored in a queue.

2.3.3 Called Line Connection:

A base level program analyzes the request for called line connection in the queue, controls the line categories and status of the called line (whether free or busy). For a free called line, a marking request is written on the register buffer. Then the path is established in clock level and the ringing phase is started. When the called party answers, control of the call is made via status buffers and called party status is changed busy.

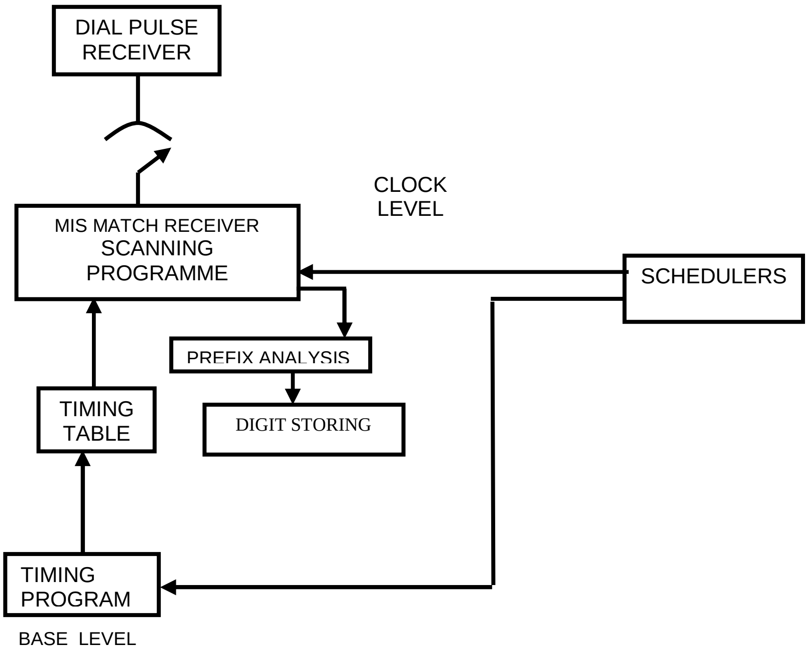


Fig. 2.3 Digit Reception

2.4. Maintenance and Administrative Programs:

Extensive programs are available for supervision of all parts of the system & detection of hardware as well as software faults. As soon as fault is detected, faulty section isolation and system restart occurs. Administrative programs are used for changing exchange and subscriber data by commands (man-machine dialogue) from maintenance consoles. Statistical programs are used to collect and compute different traffic data. Traffic supervision is possible by either supervising line traffic or by regularly running test programs.

Some built-in-fault detection programs are employed by the central control. Data sent over internal buses of the duplicated processors are compared. Voltage and time supervision is done. Watchdog routines enable processors to check each other and some test calls are generated from autonomous devices.

When any abnormal operation is detected, fault recognition program tries to locate and isolate the faulty unit. Where redundancy of the equipment is available, automatically the faulty equipment is replaced. If the fault is in central control or a memory, a reconfiguration of processors and various stores is needed and after finding an appropriate working system, restart takes place. After identification of the faulty equipment, diagnosis test programs test the faulty equipment and outputs the result by indicating the doubtful part.
If the system is unable to carry out all processing works after a central control fails, the traffic handling is resumed from a well-defined starting point. If several restarts occur within a short time period, the software is automatically re loaded from back up memories. During system restart, established calls are not affected.

Operation and maintenance of the exchange require regular operational actions. So, a man-machine communication is very much essential, which is possible via key board, VDU terminals and printers. The man-machine language confirms to a general set of rules governing the message formats.

The software designing and testing is a much demanding process. For system users, the software should have maintainability, extensibility, visibility and security. For application engineers, it should have adaptability for changing environments, case documentation and high throughput with economy. For simplification and ease of control, structured software is normally used. It should have hierarchical and modular structure with general sub-routines.

For development, production and maintenance of software on a large scale, computer aids are necessary and this needs support software that includes assembler, compiler, system file generator; office and engineering data generator.

2.5. Conclusion:

SPC exchanges use Real Time based software. Operating software takes about 1/5th volume of total, of which on line portion is again much less. Application software is mainly having Maintenance software, Call processing software and Administration software. Programs are again divided in Resident and Non-resident programs. Scheduler initiates various programs at appropriate timings. Modular and structured software is used for simplification.

Objective:

1. Operating system software is online as well as offline software in exchange. (T/F)
2. Signaling in exchange is a real time process. (T/F)
3. Mismatch treatment pertains to the dialed digits acceptable to the exchange. (T/F)
4. The path search program is used to identify a free path available for inlet and outlet. (T/F)
5. Mark and drive program is carried out by the respective hardware in the process. (T/F)
6. Data table consist of system logic and hardware information of exchange. (T/F)
7. SPC exchange have in-built-fault detection program. (T/F)
8. Self healing is done by data comparison of two duplicated units. (T/F)
9. In self healing process faulty units are in service but isolated. (T/F)

Subjective:

1. Write short notes on the following;
   a. Software need for SPC exchange.
   b. Real time processing.
   c. Call treatment program.
   d. Maintenance and administrative program.

CHAPTER 3

STORED PROGRAM CONTROL – CONTROL STRUCTURE

3.1 Introduction:

The Stored Program Control Exchanges have two types of control structures, viz., single processor control and multiprocessor (distributed) control. In the early days of Stored Program Control (SPC) systems, the control functions were totally centralized. With the availability of low cost microprocessors, the trend is towards distributed control with the use of multiple processors. In this chapter, the control structure of the SPC exchange along with the various redundancy methods adopted to ensure uninterrupted telephone service to the subscribers, are discussed. Control system architecture is shown in Table 4.1

<table>
<tr><td rowspan="3">Single Processor System</td><td colspan="4">Multiprocessor System</td></tr>
<tr><td colspan="2">One Level Systems</td><td colspan="2">Hierarchical Systems</td></tr>
<tr><td>Segmenting</td><td>Function Division</td><td>Peripheral Control

WPC Central Control SPC</td><td>Peripheral Control

SPC Central Control SPC</td></tr>
</table>

Table. 3.1 Control System Architecture.

A processor is a digital computer that continuously executes instructions of a program stored in a store (memory). SPC exchange has three types of stores.

- **Program store**: Contains the details of general working of exchange.
- **Translation Store:** Contains the analysis tables and all the data about the COS, port programming etc.
- **Call store:** Contains the entire temporary data used during the call set up.

The translation store and call store together are referred to as Data Store.

3.2 Single Processor System:

The single processor system is illustrated by means of Block Diagram in Fig.3.1

As the Central Control was only one, bus systems were used In this architecture, to connect the Central Control to the various points in the switching network and other peripheral equipment, to cater for the necessary sensing and control functions. This type of architecture had its own undesirable characteristics.

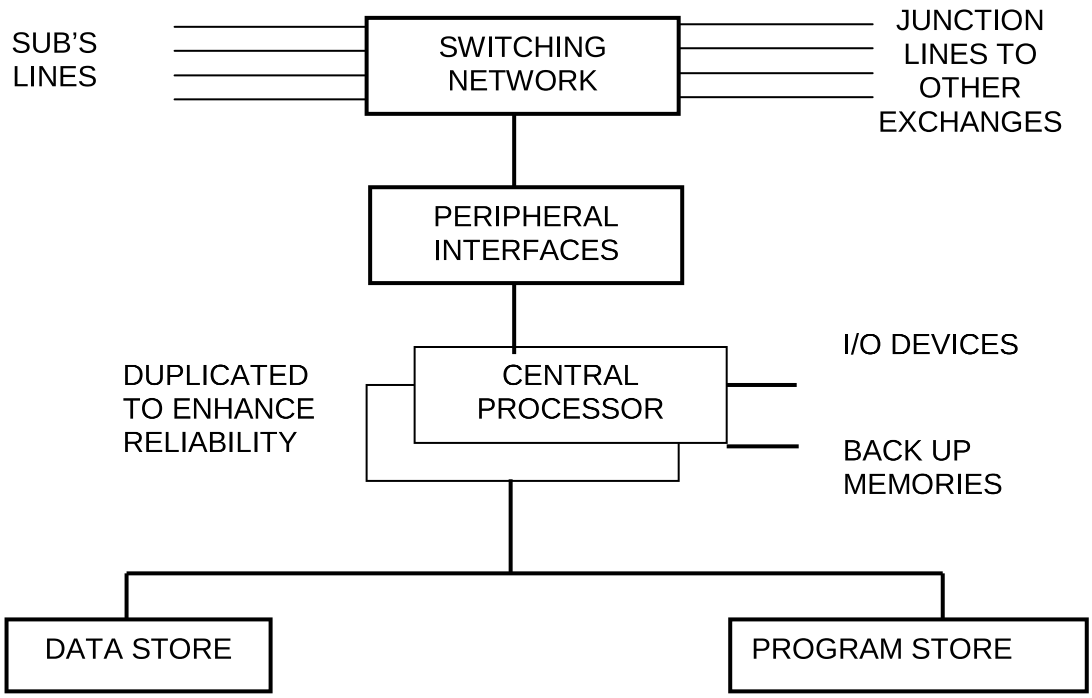


Fig.3.1 Single Processor System

Even though the Central Common Control was quite fast operating, it has to handle all the call set up functions in a sequential order. The call handling capacity of the common control was finite and during the busy hour with a lot of call attempts and with shorter than expected average holding time, the common control equipment was not able to process all the calls, resulting in service deterioration. Various special features common to SPC systems place additional load on the Central Control as these require large amount of real time of the common control, than required for setting up a normal call.

Besides, the bus structure makes the system vulnerable and if duplication is provided, the software complexity increases. The Bus also has finite capacity and presents one more bottle neck in this system

3.3 Multi Processor System:

A multiprocessor system is a control system, where more than one processor is used to perform the logical functions involved in the establishment, control and release of call in the telephone exchange. Multiprocessor systems can be one level system or hierarchical system.

In One level system, the processors work side by side and the entire load is divided amongst them.

In Hierarchical systems, the central processor carries out the logic functions, while less intelligent and repetitive tasks which consume large capacity are delegated to a number of smaller processors.

The general structure of one level multiprocessor system is shown in Fig.3.2. The total workload of the exchange is divided among N processors CP-0 to CP-N. The size and capacity of the exchange can easily be increased, by just adding new processors. Each processor has its own individual store and in addition there is a common store shared by the N processors. The individual stores normally include program stores and sometimes also translation and call stores. The common store can be used to store programs that are not used very often. It can also be used to store translation and call stores. It is also used as a **Mail Box** for communication amongst its processors.

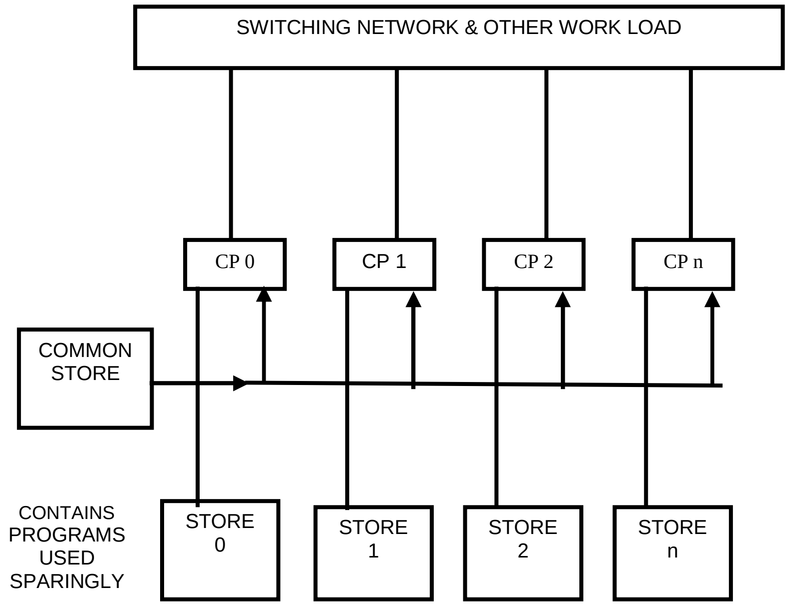


Fig.3.2 One Level Multi Processor System

3.4 Function Division and Segmenting:

The N processors can divide the work in accordance with two main principles, viz., **function division** and **segmenting**.

In the case of function division, we have several processors. Each of takes care of certain functions for the whole of the exchange. In this case, only parts of programs are loaded into each individual store. Translation and call data may be located in the individual stores or in the common store. The principle of function division has the advantage that each of the processor can be better adopted to carry out just those particular functions that are allocated to it. The disadvantage is that from the beginning, the processors must be dimensioned for the final capacity of the exchange.

EXTENSION UNITS

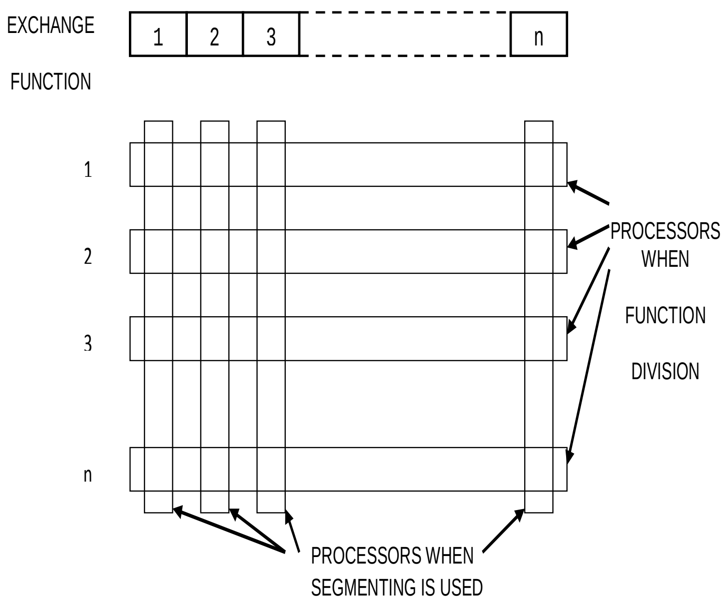


Fig.3.3 Functional Division & Segmenting

Segmenting means that each processor carries out all the functions only for a certain segment of the exchange, as an extension module, as shown in Fig. 3.3. Facilitates easy capacity extension.

In actual systems, a judicious combination of both the principles are employed

3.5 Hierarchical System:

In the SPC system, there is a relationship between the complexity of the logical functions and the frequency with which they are used. Complex functions are rarely used whereas simple functions, such as scanning of test points, are used frequently. All the capacity consuming routine functions are preferably located in the peripheral control while not often used complicated tasks are allocated to the central control.

The logical functions can be allotted to the peripheral and central control in various ways. Functions like scanning of test points, digit recognition etc., are often allocated to the peripheral control. The central control normally takes care of the universal functions, the functions that concern the whole exchange. Administrative functions, fault diagnosis, man-machine communications, path selection, digit analysis and charging functions are examples of centrally located functions. In Hierarchical system control is divided into following levels:

The first control level handles Scanning, Distribution and Marking functions and is physically close to the Switching network, Junctures, Subscriber lines, etc. The control equipment for these functions are called Switching Peripherals. These peripherals are characterized by: -

- **Processing Operation Functions:** Specialized but simple and repetitive in nature. To implement processing functions
- **Modular hardware:** Facilitates capacity extensions. This also limits the fault liability to a small section.

Each peripheral unit has two parts:

Processing part: Generally a Microprocessor, communicates with the other two control levels.

Terminal part: Contains the interfaces with scan points, cross points and distribution points, entirely controlled by the second Level, the call processing level.

The second control level is the heart of the control system, being responsible for call processing. This processes the information received from the first level. This level controls establishment and release of calls by issue of appropriate orders to the peripheral control devices. Stored program control is used invariably for this.

The third control level handles operation and maintenance functions involving communication with exchange personnel. Most of the information is obtained from the second level. This level also uses stored program control. The real time and availability constraints are less than for level two. The volume of software is, however, large.

The level three processor can be made to serve a number of exchanges and can be located at some distance from the exchange.

In some cases the Central Control is common to many exchanges, while the peripheral units perform the control of the individual exchanges. In these cases, it is preferable to allocate **'Exchange Oriented'** functions to the peripheral units and **'Network-Oriented'** functions to the central control.

3.6. Common Control Redundancy Methods:

A telephone exchange must guarantee service to the subscriber under all circumstances. Failure cannot be accepted in exchanges under any condition. Duplication must be provided for all common control devices and it must be ensured that the exchange continues to operate even if any of these devices are taken out of service for any reason.

For common control equipment, normally provided in-group of several units (N), each is having identical function. The two main methods are

Each equipment unit is fully duplicated so that if one fails, the other can take over the function as shown in Fig.3.4.

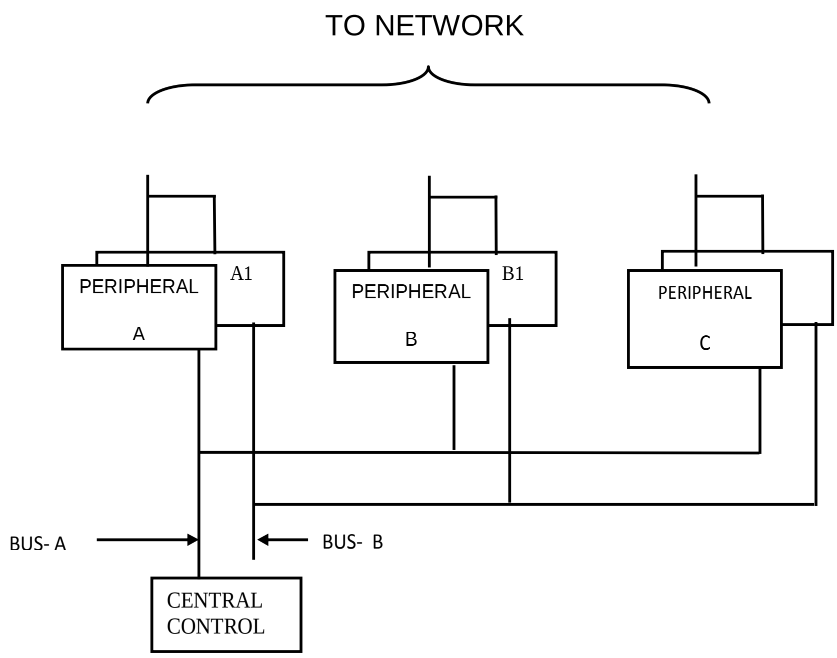


Fig.3.4 Full Duplication.

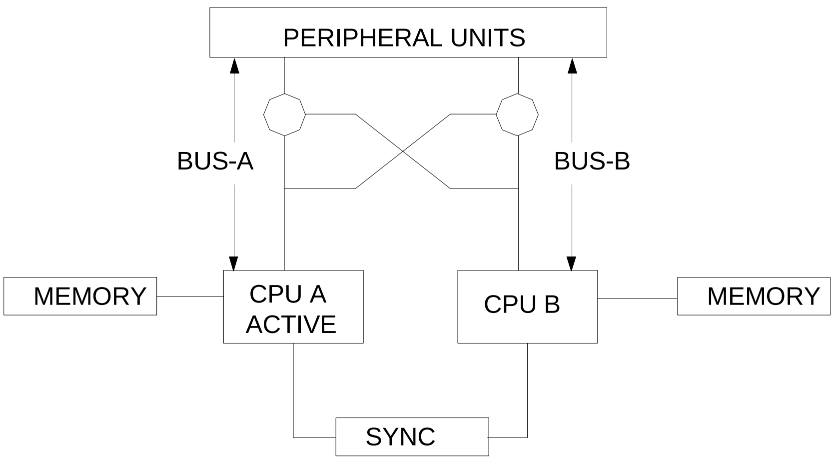
Alternatively, one standby unit is provided, bringing the total of units equal to N+l, so that if one should fail, the spare unit can take over. This method relies on the probability that only one unit will fail during the time needed to repair or replace the faulty unit.

Regarding the central processor unit, redundancy in general is provided by following techniques: -

- Synchronous Replica Duplication.
- Load Sharing Method.
- N + I Redundancy Method.
- Passive Standby Method.

3.6.1. Synchronous Replica Duplication: (Fig.3.5)

In this system, the two identical processors carry out the same operation simultaneously. To permit this, both processors have to use obviously the identical program, and receive the same data from the peripherals, concerning external events and action taken. Both processors are for this reason synchronized by one time clock. Permanent comparison between these processors allows the instantaneous detection of any divergences between the content of their registers due to error. This identifies the faulty processor, isolates, from the circuit and gives a visual alarm. When both processors are healthy, only one processor at a time is allowed to send instructions to the telephone peripherals.



Under normal conditions, the second processor is only an active standby in respect to peripheral control. This system configuration guarantees immediate detection of error, but when an error has occurred, a recovery procedure must ensure that the faulty equipment is rapidly detected, the seriousness of the error is assessed and if needed the memory content of the faulty unit is restored.

3.6.2. Load Sharing Method:

The load sharing principle is illustrated in Fig.3.6. Load sharing means that both processors are working independently of each other in such a way that each of them handles half the traffic load under normal conditions. To permit this, the two processors A and B are controlled each by their own clock system, which are synchronized, but shifted by 90 degrees.

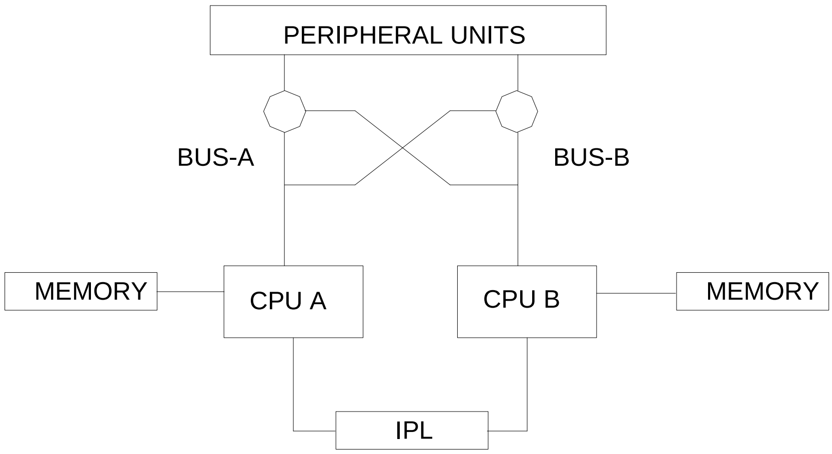


Fig : 3.6 Synchronous Duplication Load Sharing Method

In order to be prepared against an eventual out of service condition of one of the two processors, each one has to have full knowledge of the conditions of the established calls, under control of the other processor. In this way, should one processor go out of service due to any reason, all established calls will be saved and treated correctly, and only the calls in progress in the faulty processor will be lost. This, however, in view of the high reliability of the central control units is acceptable. To facilitate mutual information between the processors A and B, an inter processor message link system exists. The use of inter processor message avoids the probability of both processors accessing the same peripheral devices at the same time. As both the processors are normally working in the **duplex mode** and as each one handles half the load, the full duplex system is capable of handling 1.6 times the traffic that can be handled by a system configuration based on the synchronous replica duplication method.

3.6.3. N+1 Redundancy System:

Some multiprocessing systems use the N+1 system configuration as shown in Fig.3.7 & 3.8 in which one processor is added as a redundant unit. This unit under normal conditions takes part of the traffic handling, so that the total N+1 configuration has a larger capacity than the engineered capacity based on N processors.

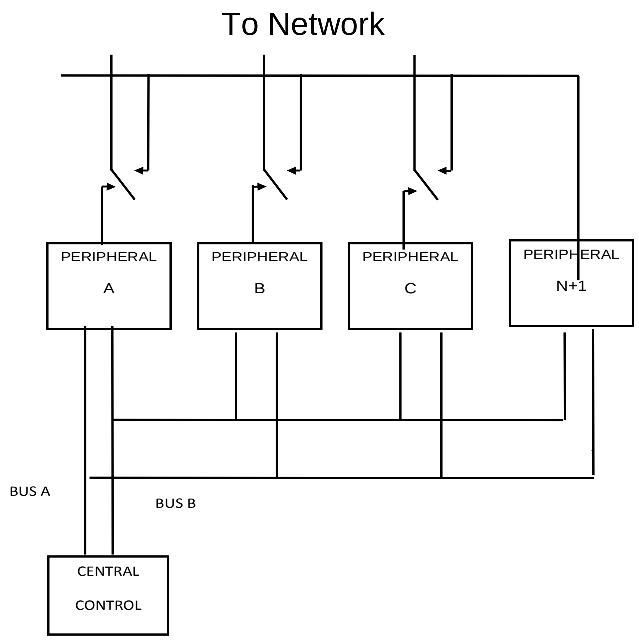


Fig.3.7 N+1 System

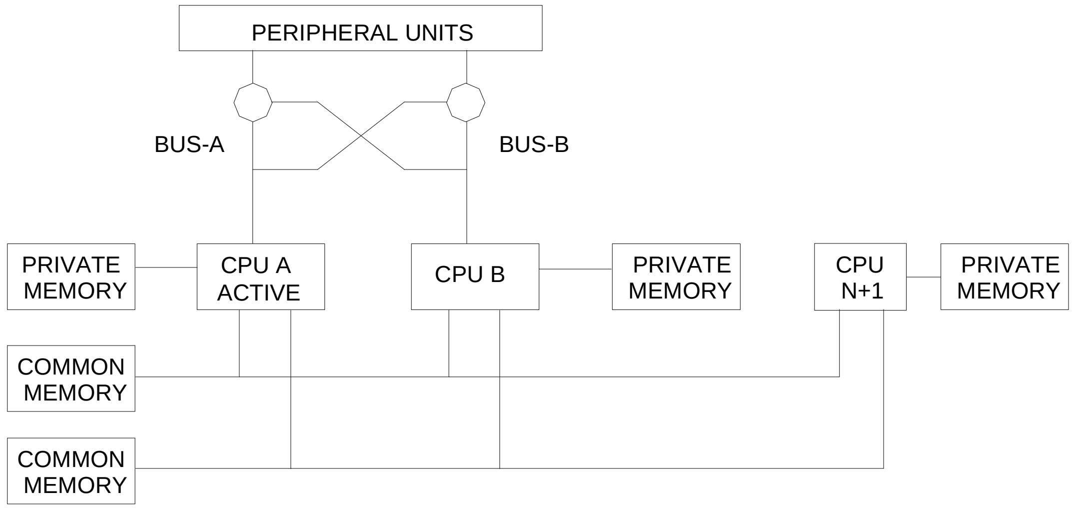


Fig : 3.8 N + 1 Processor Configuration

3.6.4 The Passive Standby System:

The passive standby method is based on the synchronous replica duplication method with the difference that no synchronization and mutual control is used as shown in Fig. T 12D.4.9. If the active computer fails, the other computer is placed on line by means of a recovery procedure. All the data is stored in memory and as both processors have access to this memory, established calls are not lost.

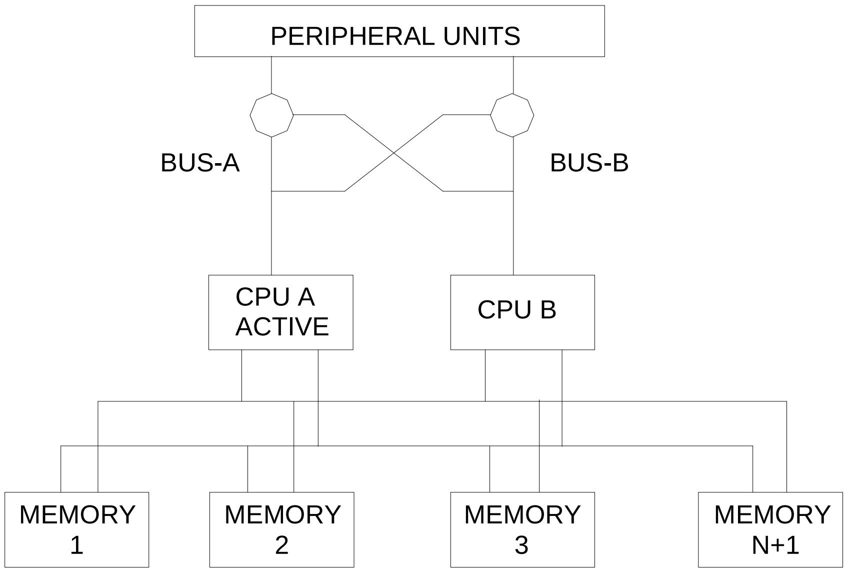


Fig : 3.9 Passive Standby System.

3.7. Merits & Demerits

The relative merits and demerits of the single processor and multiprocessor control structure is the subject of heated debate. In fact even in the case of central control system, a number of satellite processors are employed. It can be said that in the single processor system, there is only one decision making center the central processor. Distributed Control on the other hand contains at least two mutually exclusive decision making centers.

The supporters of the Central Control architecture stress that since operation, supervision, maintenance and traffic Control functions require large Databases and a considerable amount of memory, a Central Data processing system can handle these requirements efficiently. The disadvantages of this system are the increased probability that the processing power may become inadequate during high traffic operations and the possible risk of total breakdown of the system.

The Distributed Control architecture on the other hand is less prone to total breakdown. Drawbacks include difficulties in task distribution and the substantial increase in software for internal signaling purposes amongst the various microprocessors.

Objective:

1. SPC exchanges have two types of control structure, single processor and multiprocessor. (T/F)
2. In distributed control system more than one microprocessor are involved. (T/F)
3. Program store contains the details of general working of exchange. (T/F)
4. Translation store contains analysis table, port programming and data base. (T/F)
5. Call store is a temporary data of call setup. (T/F)
6. Duplication of CPU card is done to enhance the reliability of exchange. (T/F)
7. In multiprocessor system the translation store and call stores are available with each processor. (T/F)
8. Multiple processor also share call store. (T/F)
9. Principle of segmentation is used to carry out functions from different microprocessor. (T/F)
10. Scanning marking and distribution are dealt in first level of control system. (T/F)
11. Call processing is dealt in the second level of control system. (T/F)
12. Maintenance and administrative functions are dealt in third level of control system. (T/F)
13. Duplication of common control card is done to ensure round the clock service from exchange. (T/F)
14. To select the best CPU in working condition inter processor link is provided. (T/F)

Subjective:

1. What is SPC? Explain different types of processor system?
2. Write short note on program store, translation store and call store.
3. Short note on
    a. Multiprocessor store system
    b. Single processor store system.
4. Write short note on load sharing method.
5. What is the function of Inter processor link?
6. What are the merits and de merits of SPC?

CHAPTER 4

SIGNALLING FOR TELEPHONE NETWORKS

4.1. Introduction

Signaling has been identified as one of the three functional divisions of any switching system, the other two being switching and control. Signaling plays the important role of conveying intelligence needed to enable a subscriber to contact any other subscriber on the switching system or in the network.

Signaling provides -

- The basic information for the establishment of the calls
- Information to the subscriber that the switching system is ready to accept his call (Dial tone)
- Alert signal to the called subscriber about an incoming call (Ringing Voltage)
- Information to the calling subscriber (Ring Back Tone.)
- Information to the calling subscriber, if called subscriber is engaged (Busy Tone)
- Supervision of calls already established
- Guarding control signals to protect engaged subscribers
- Release signals to release all associated equipment when call is disconnected
- Release signals to remove guarding control
- Metering pulses for call charging

It can, therefore, be said in short that signaling provides the necessary information for: -

- Establishment of a speech path between the end users may be two subscribers within the same exchange or different exchanges
- Exercising supervision over the established calls, by holding the speech path and preventing the same being seized by other subscribers
- Disconnect the speech path at the end of the conversation, thus, freeing the exchange equipment for the use of other subscribers

4.2. Classification of Signaling

Signaling can be classified in a number of ways depending upon the equipment, mode of operation, sub functions, etc.

4.2.1. Classification depending upon subscriber:

- Subscriber signaling (in case of local exchange sub)
- Inter exchange signaling (in case of another exchange sub – distant sub)

4.2.2. Classification depending upon signaling philosophy:

- **Channel Associated Signaling (CAS):** The signaling information of each channel is carried and transmitted in the same speech channel itself or in a signaling channel permanently associated with it.

  In Analogue FDM systems, the same speech channel carries the signaling information also. Even though the time slot for a particular speech channel and analogue time slot for signaling are different, the signaling time slot is permanently associated with the corresponding speech time slot.
- **Common Channel Signaling (CCS):** The speech path and the signaling path are entirely different. Signaling information for a number of speech channels are conveyed over a common signaling channel in which signaling message consists of a group of bits with a defined structure and content. Each signaling message contains a label to identify its associated speech circuit. As the signaling links are separate from and independent of the speech channels, full signaling capability is available.

4.2.3. Classification depending upon signaling technique with regard to timing:

- **Semi continuous signaling techniques:** Signals are transmitted for a period of time equal to that of the duration of the state , which caused the emission of the signal. **Tone on -Tone off** signaling.
- **Pulsed type signaling:** Employs pulses formed by impulsing circuit. Either a single frequency or a combination of frequencies is used. The various signals present in the signaling systems are defined by two basic criteria **signal duration and signal sequence.**
- **Compelled type signaling:** Signals are transmitted until an acknowledgement is received. The acknowledging signal is transmitted until the transmission of the initial signal ceases.

4.2.4. Classification depending upon signaling on the mode of operation:

- **Link-By-Link signaling method:** The address information is transmitted from the originating exchange to the next exchange where the information is analyzed and then re-transmitted to the next exchange. The procedure is repeated until the information regarding the called subscriber reaches the terminating exchange to which the called subscriber is connected.
- **End-To-End signaling method:** The originating exchange directly controls the setting up of the connection. It transmits to each successive exchange only that

portion of the information that is required to establish the connection to the next exchange. The address information determining the routing in the transit exchange is not re-transmitted by the intermediate exchanges, which provides only a transparent path.

4.3. Types of Signals:

Having discussed the various types of classification of the signaling systems, let us now discuss about the types of signals depending on their functions. Types and sub-types of signals are :

1. Supervisory Signals.
   a. Control
      i. Forward
      ii. Backward
   b. Status
      i. Idle
      ii. Busy
2. Addressing Signals
   a. Station
      i. Rotary dial
      ii. Push button
   b. Routing
      i. Channel
      ii. Trunk
3. Audible-Visual
   a. Alerting
      i. Ringing
      ii. Busy tone
   b. Progress
      i. Dial tone
      ii. Ring back

4.3.1. Supervisory Signals:

Supervisory signals are those that monitor the status of a subscriber's line, junction or trunk circuit to determine if they are idle or busy or requesting service. Supervision covers the detection of condition or changing of state of some element in the switching network, such as subscriber going off-hook, seizing of a circuit or releasing of a call etc. In other words, the supervisory signals are those necessary to initiate a call set up, supervise the call once it has been established and release the switching equipment once the call is over.

4.3.2. Address Signals:

Address signals convey the called subscriber's address, routing information over the network in the form of signals such as Pulses (Rotary Dial), Tones (DTMF signaling) in case of local subscriber and in case of junction and trunk circuits, by means of multi frequency tones and data pulses.

4.3.3. Alerting Signals:

Alerting signals are normally in the form of audible and visual signals to indicate to the subscribers and the exchange about the various conditions for further action by the subscribers or exchange equipment. Typical examples are the off-hook information conveyed by the lifting of the handset by the subscriber to the exchange and ringing voltage from the exchange to alert the called subscriber. The various tones such as Dial Tone, Ringing Tone, Busy Tone etc., enable progress of the call set through the various stages.

4.4. Line Signals and Register Signals:

The supervisory and address signals are also known by the names Line signals and Register signals respectively.

4.4.1. Line signals:

Are employed for seizing of a circuit and supervision of a call. Line signals can occur at any time during call processing by their very nature. Line signals are
much easier to handle as only a limited range of signals such as On Hook / Off Hook, Idle / Busy etc., have to be handled. The equipment is, therefore, quite simple and as each line and junction or trunk circuit has to be monitored for supervision purpose continuously. These are permanently associated with each line or circuit. Line signaling can be accomplished by means of several transmission methods, such as DC Loop (for local trunks), In Band or Out of Band signaling etc.

4.4.2. Register signals:

Are utilized to transmit the called subscriber number or other routing information needed to set up the connection. Since the Register or Address or Routing signals occur only for the short duration of time for call set up, the equipment required to handle register signals need not be provided on individual basis and can be provided in limited numbers to be shared by a number of subscribers and circuits to meet traffic requirements. Register signaling can be accomplished in two ways.

- With same transmission means as line signaling (e.g.) decadic pulsing over DC loop, in band or out of band signaling.
- With a special register signaling system such as multi frequency signals.

4.5. Supervisory Signals:

As can be seen from Table 1, supervisory signals are Seize, Hold and Release signals controlling the setting up, holding and release of the calls through the switching network. The Idle, Busy and Disconnect signals monitor the status of the subscriber and exchange switching equipment indicating whether the equipment is idle or busy etc.

As we are all aware, the idle or busy condition of the subscriber equipment is determined by the condition of the subscriber loop (i.e.) whether the handset of the subscriber telephone instrument is ON Hook or OFF Hook. No current flows through the subscriber’s loop when the handset is ON-HOOK and in the OFF HOOK condition there is a DC shunt across the line and hence flow of current through the subscriber's loop. The OFF HOOK condition is recognized at the exchange by the operation of the Line Relay in the case of electromechanical exchange and by suitable current sensing device in the case of electronic exchange. The OFF HOOK condition (i.e.) the status of the subscriber who has lifted the handset will have to be indicated to the other subscribers, trying to establish connection with that subscriber.

In the case of both way junctions or trunk lines, the **On Hook** condition will have to be indicated towards both the ends. The signaling system should be able to detect and prevent seizure from both ends simultaneously.

Once the call is set up between the calling and called subscribers, the speech path is held and is prevented from being seized by any other call attempt. This is the holding function of the call. At the end of the conversation, the speech path will have to be released depending upon whether it is calling party release or either party release.

4.5.1. E & M Signaling:

E and M Signaling is the most common form of Trunk Supervision. The supervisory signals are transmitted by the use of a single control channel in each direction in parallel with the speech channel. The leads of the signaling channels are referred to as E and M leads. E represents the receiver or the Ear. M represents transmitter or the Mouth. The status presented at the M lead at the transmit end is reproduced at the E lead at the receiver end. The actual method of providing the signaling channel depends upon the transmission technique used for the trunk circuit.

In the case of physical pairs used as trunk circuit, there is a DC path between the two ends and the signalling from the transmitting to receiving end of the trunk can be performed by the loop condition at the transmitting end, whether Open or Close. In the case of long distance trunk circuits making use of FDM techniques, line signalling information is transmitted by sending a tone which is controlled by the M lead over the speech channel. The tone may be inband (i.e) within the speech band 300 to 3400 Hz., or out of band (i.e) beyond 3400 Hz.

- In-Band signaling, though simpler, has the drawback that there is a possibility that speech signals are interpreted as control signals. To prevent an already established call being cleared by a false signal, a Guard circuit is normally employed. In this, if there is speech energy outside the signaling frequency, the false signaling is prevented from clearing the call. For a reliable **Clear signal**, there must be energy at the signaling frequency and no energy in speech band. In band signaling can be of single frequency usually around 2600 Hz., or two frequencies 2400 Hz and 2600 Hz. Single frequency is used for supervisory function whereas two-frequency system is used both for supervision and addressing.

IN-BAND AND OUT–OF–BAND SIGNALLING

In Out of Band signaling, the signaling frequency is normally 3825 Hz. and always only one frequency is used. The On Hook or Idle condition can be indicated with the Tone ON or Tone OFF. False operation is not possible, as the tone is outside the speech band. When channel patching is required, the E and M leads will also have to be cross connected. Continuous supervision is provided during the entire telephone conversation.

The principles of In-Band and Out of Band signaling are illustrated in Fig.4.1.

In PCM system, signaling bits used for E and M signaling are transmitted in the Time Slot 16 of each frame. Normally the Time Slot 16 carries the signaling information for two channels. As each Time slot consists of 8 bits, 4 bits are available for the transmission of signaling information of each channel, which is more than sufficient for the purpose.

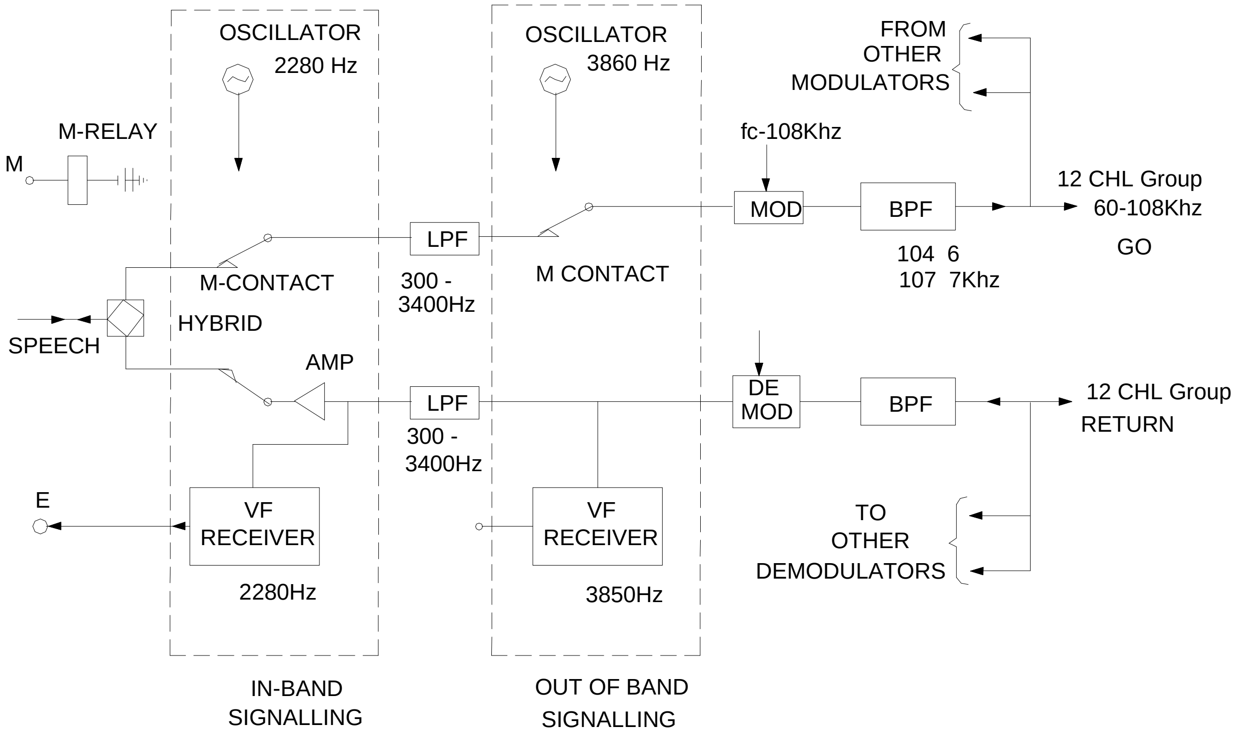


Fig : 4.1 PRINCIPLE OF IN-BAND AND OUT-OF-BAND SIGNALLING

4.5.2 Reverse Battery Signaling:

Another method of supervisory signaling used on trunk circuits on physical wires is Reverse Battery Signaling as illustrated in Fig.T12 D.4.2.

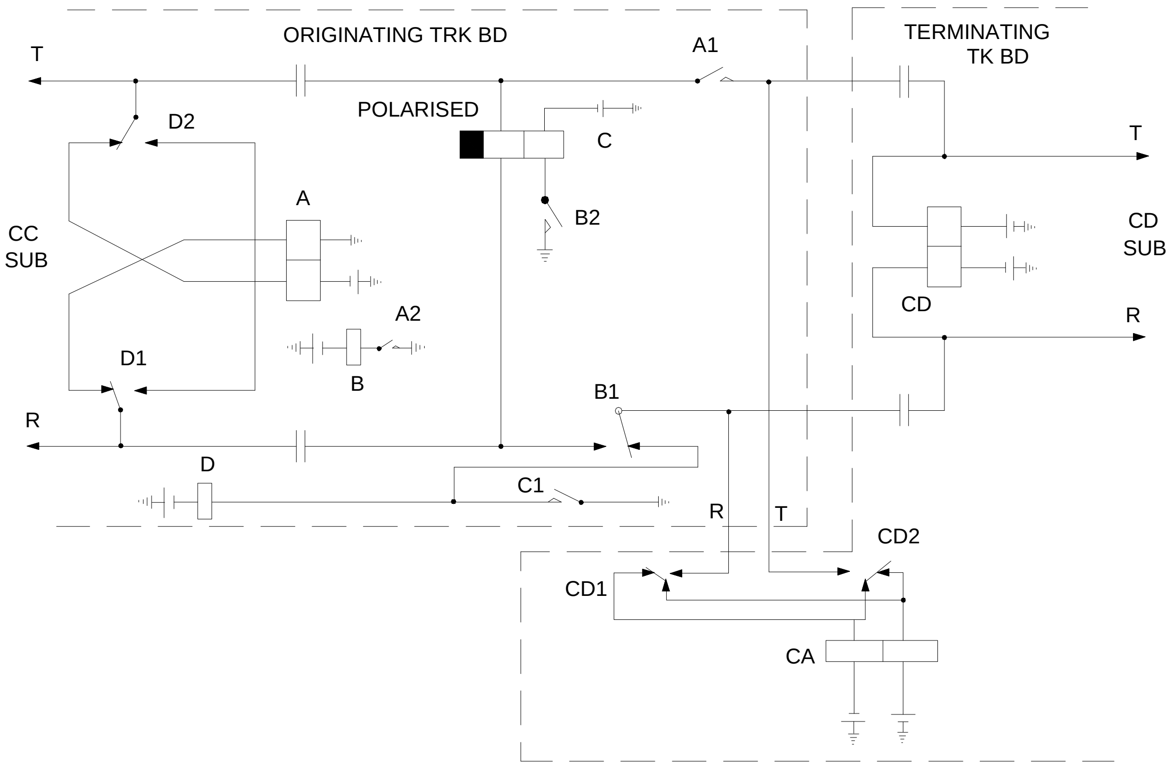


Fig :4.2   REVERSE BATTERY SIGNALLING

The On Hook and Off Hook conditions are given by the polarity across the loop (i.e.) the direction of current flow. Polarity in the case of trunk loops refers to **Battery and Ground** state. In manual switchboards, the TIP and RING of the plugs and Jacks used to represent the two leads. Following the same convention, the Off Hook condition places the Battery on the TIP and Ground on the Ring of the plug. The On Hook condition has reverse current conditions with Ground on Tip and Battery on the Ring of the plug.

4.6 AC signaling:

Direct current signaling cannot be used on carrier system and on physical wires of long lengths. In such cases, AC signaling is resorted to, which can be of three categories: Viz.

- Low frequency AC signaling
- In band signaling
- Out of Band signaling

In band and out of band signaling have already been discussed. AC signaling systems operating below the conventional voice channel (i.e.) less than 300 Hz. are called low frequency AC signaling systems. These are single frequency systems, the frequencies being typically 50 Hz., 80 Hz., 135 Hz., or 200 Hz. These are not capable of being operated in carrier systems and as such their use is limited to physical wires up to a maximum distance of 80 to 100 km.

4.7 Address Signaling:

Address signaling is nothing but the digits dialed by the calling subscriber to identify the location of the called subscriber. The dialed digits are accepted by the central control and by making use of these digits, identifies the called subscriber. The status of the called subscriber is then checked through the sub-function of supervisory signaling and in the event the called subscriber is free, sets up the speech path between the calling and called subscribers. The address signals are needed only during the call set up.

The address information of the called party may be either in the form of Rotary Dial Pulses (Decadic pulsing) or Voice Frequency signals. The Rotary Dial Pulses are with a nominal 10 pulses/second and Break/ Make ratio of 67:33. In direct control systems, as the dial impulses will have to operate the two motion selectors directly, the tolerance on the number of impulses per second is quite stringent viz., 9 to 11 pulses/second, with break to make ratio between 60:40 and 70:30.

In the case of common control exchange, this can be less stringent, the pulses between 7 to 14 per second and the Break to Make Ratio between 50:50 to 75:25. The inter digital pause in all cases should be more than 350 milliseconds.

In recent years, push button telephones have become quite popular. Push Button dialing is also known as Dual tone Multi-frequency signaling. In the push button dialing, simultaneous transmission of two frequencies - one from a low frequency group and another from the high frequency group - is effected. With the standard 3 x 4 keys, 12 combinations are possible of which 10 are used to represent the digits 0 to 9. The two extra combinations, the star and square are normally used for supplementary services. However, in order to have DTMF signaling, suitable equipment should be provided in the exchange, capable of receiving the tones and converting them into appropriate digits to enable the control to identify the called subscriber and establish the speech path between the calling and the called subscribers.

DTMF signaling is quite fast compared to the dial pulsing. Whereas in dial pulsing 10 pulses per second are sent, in the DTMF signaling digits are sent at the rate of about 7 digits per second. The DTMF signaling is, therefore, much faster than signaling by dial pulses.

DTMF dialing has other advantages apart from faster signaling. With the introduction of International Direct Dialing facilities, the number of digits to be dialed is quite considerable and hence the time required to complete the dialing is quite considerable. Besides, the chances of the wrong dialing and impulsing errors are more in the case of dialed pulses than in DTMF dialing.

We had earlier seen that the Off Hook condition, when the subscriber lifts the handset, is a supervisory signal. In the case of lifting the handset, the signaling condition is indicated by the closing of the subscriber loop. Dialing also can be considered as merely as an interruption of the subscriber’s loop off hook condition in the form of **make and break**. Make is the off hook condition when current flows through the loop and break is on hook condition when no current flows through the subscriber's loop. The distinction between supervisory and address signaling is made possible mainly by the duration of the on-hook condition. In the case of dialing, the duration of On Hook condition is quite small, whereas the On-Hook condition when the subscriber replaces the receiver after the conversation is for a longer duration. It is this difference between the duration of the ON-HOOK condition that enables distinction of the supervisory and address signaling.

4.8 Register Signaling:

Two frequency signaling is commonly used for register signaling purposes. A number of two frequency signaling methods were evolved from time to time and the system adopted in India is the CCITT R 2 signaling system. In this two, out of six frequencies, which can give 15 different combinations are used. By employing two groups of six frequencies, Group 1 for the forward direction and Group 2 for the backward direction, a total of 30 combinations are possible. The address information and the nature of the call indicated by the 30 combinations of frequencies are given in Table 4.2.

Frequencies in Hz						
Group 1	1380	1500	1620	1740	1860	1980
Group2	1140	1020	900	780	660	540

Table 4.2 CCITT R2 Signaling Frequencies

The R2 signaling has two versions - one used for Analog Networks and the second one used for PCM networks. Compelled signaling technique is used to transmit forward and Backward Register signals. The R2 signaling system has the following characteristics.

- It can be used on both 2 wire and 4 wire circuits.

- A large amount of information can be transmitted with a high degree of reliability.
- It has a short post-dialing delay.

4.9 Common Channel Signaling:

In the Channel Associated Signaling, each speech channel carries its own signaling, both supervisory (line) signaling and address (Register) signaling.

With the introduction of Stored Program Controlled exchanges, making use of Central Processors, which enable call set up to be carried out quite fast, the need for an equally fast, reliable and efficient signaling system was felt, which has resulted in the parallel development of the common channel signaling system, also based on a central processor for signaling.

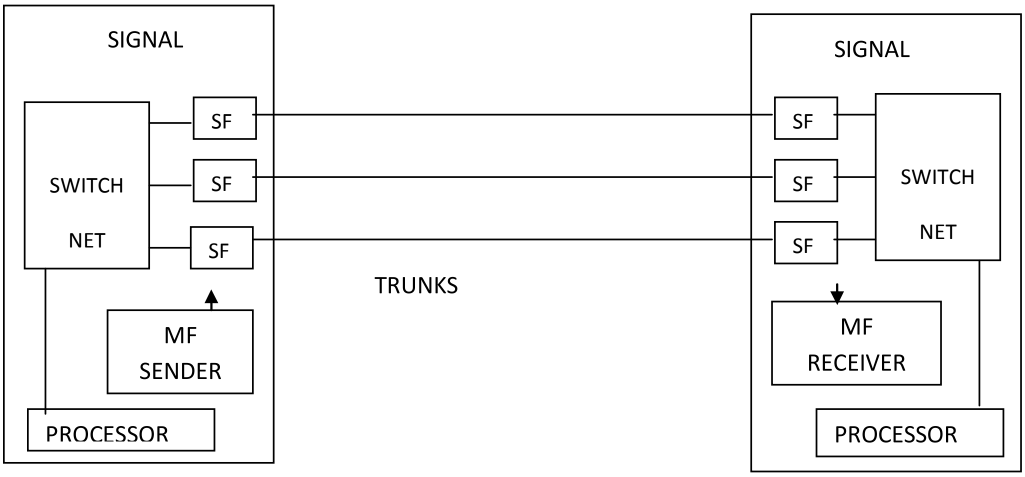
The switching control and the common channel signaling control can be handled by the same central processor, if adequate capacity is available or by use of distributed processing (i.e.) separate processors for control and signaling.

If signaling functions are handled by a separate processor, it is advantageous to separate the signaling from the speech channel and establish a separate data link between the signaling processors of different exchanges to handle the various signaling functions in setting up, holding and release of a call.

Common Channel Signaling, therefore, separates signaling from its associated speech path by placing the signaling for a group or groups of speech channels on a separate path dedicated to signaling only. Signaling on the telephone network is basically binary in nature (i.e.) it has only two possible states. Viz., On hook or Off hook, idle or busy etc. The signaling information on common channel signaling is transmitted in the Binary Format. The basic distinction between the conventional signaling and common channel signaling is shown in Fig. 4.3.

Each signaling link consists of a data link with terminal equipment at each end, and typically performing functions necessary for the orderly and correct transfer of signaling information, such as Error Control, Identifying the signaling information pertaining to different channels, etc. The CCITT No. 6 system evolved earlier makes use of 2.4 Kbps data link, optimized for use in Analogue networks can deal with 2048 trunks. The line and register signaling information pertaining to a particular trunk is transmitted in one or more of the 28 bit packets (20 bits for information and 8 bits for error checking). The first packet relating to a new signal for a particular trunk contains the indication of the number of packets and an identifier for the particular trunk.

With conventional signaling, the speech path and signaling path occupy the same channel. Since signaling is effected prior to setting up of the call, continuity of the speech path is automatically ensured. In common channel signaling since the speech path and signaling path are different, the speech path continuity will have to be checked up through other means before the call is put through.



Conventional single frequency multi frequency signaling

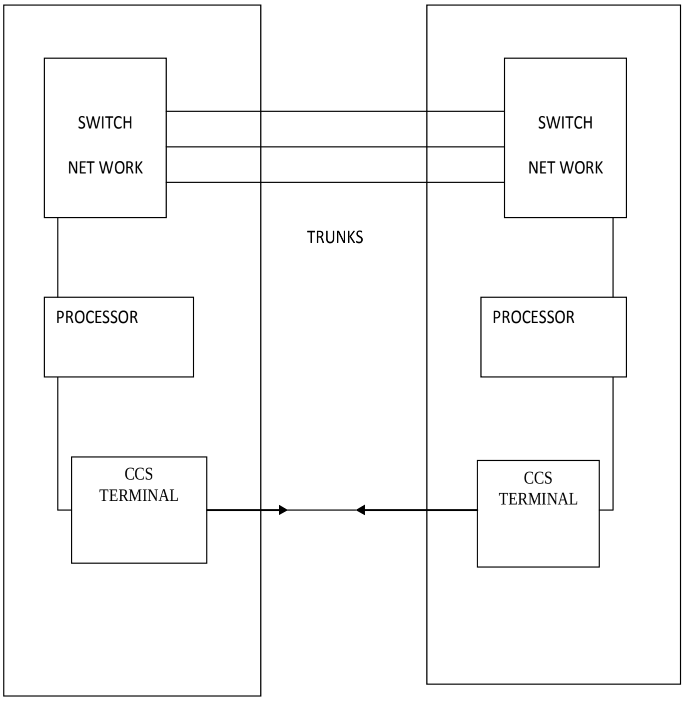


Fig.4.3 Common channel Signaling

The CCITT No. 7 signaling system is developed for use in a Digital environment using a signaling link of 64 Kbps. It is also suitable for use at lower signaling rates and in an Analogue environment.

The basic characteristics and advantages of the common channeling systems are as follows:

- Physical and functional separation of the signaling network from the speech network:
- Higher speed of signaling, compared to conventional system, implies decrease in post dialing delay and in holding time of switching equipment and circuit.
  - Simultaneous signaling both ways.
  - Capacity only limited by the speed of the data link and the processing capacity of the processors,
  - Flexibility in operation of the network.

4.10 Alerting Signals:

Alerting signals are usually audible and / or visual signals used to alert the subscriber or the operator about the call. Familiar type of alerting signals are the Ringing voltage applied to the called subscriber to alert him about an incoming call, Dial tone as it alerts the calling subscriber to commence dialing the required called subscriber's number. The howler to warn the subscriber of the off hook condition of his receiver, etc.

In case of Trunk Board the request for a connection to a subscriber of a distant exchange is normally indicated in the visual form by the lighting of a lamp, which is an example of the visual type of alerting signal.

4.11 Signaling and post Dialing Delay:

Post Dialing Delay is the time duration between the dialing of the last digit of the called subscriber's number and the time ringing is applied to the called subscriber. In Direct Control systems, the setting up of the path is directly under the control of the calling subscriber and as soon as the last digit is dialed, ringing is applied to the called subscriber and as such the post dialing delay is practically zero.

- In common control systems, however, the dialed digits are separated from path setting, and a path selection procedure is initiated by the common control. In certain cases, alternate paths will have to be tested and this contributes to post dialing delay. While this delay can be quite small in the case of a local call, in the case of a call to a distant exchange which has to be passed through a number of Transit/Tandem Exchanges, the post dialing delay is considerable.

4.12 Conclusion:

The role of signaling is an important one in any switching system. Besides conveying the information needed to establish a call, signaling provides supervision of the calls already established and releases the exchange equipment for use by other subscribers as soon as the call is over.

While the supervisory signals monitor the stations of the subscriber line and the various exchange equipment, the addressing signals route the call through the various stages to the called subscribers.

In the case of inter exchange signaling namely E & M signaling, either in band or out of band or multi frequency signaling is normally adopted. Until recently, the signaling system in vogue is the channel associated signaling in which the signaling is carried out on the same channel as that of the speech. With the introduction of SPC Exchanges and the need for faster call set up, common channel signaling has been introduced in which the signaling information of all the channels are carried in a separate link distinct from the speech channels. Common channel signaling requirement of integrated speech and data channels is a requirement to cater for the networking computers.

Objective:

1. The basic need of signaling in exchange is to establish the call. (T/F)
2. Signaling is dependent on equipment and mode of operation. (T/F)
3. Local exchange signaling is called as subscriber signaling. (T/F)
4. Inter exchange signaling is called as trunk signaling. (T/F)
5. CAS and CCS are two methods of signaling. (T/F)
6. In CAS, the signal information is sent along with the channel. (T/F)
7. In CCS, the signal information is commonly sent on separate channel. (T/F)
8. Tone ON and Tone OFF signaling is a semi continuous signaling. (T/F)
9. Pulse type signaling employs pulses formed by impulse circuit. (T/F)
10. Signaling in general denotes change in state. (T/F)
11. In end to end signaling method, the intermediate exchange provides only a transmission path. (T/F)
12. Audible-visual signal are for alerting the subscriber. (T/F)
13. Progress signals are dial tones and ring back tones. (T/F)
14. Dialing digits from the subscriber is called as address signaling. (T/F)
15. DTMF signals are faster than pulse signal. (T/F)

Subjective:

1. Write short note on classification of signaling.
2. What are different types of signals? Write in short.
3. Explain with the help of a diagram, how two exchanges are connected on e&m trunk?
4. Write short note on address signaling.
5. Write in short about CCS and CAS system.

CHAPTER 5

BASICS OF TELECOMMUNICATION TRAFFIC THEORY

5.1. Basics of Traffic Theory:

Traffic is defined as either the amount of data or the number of stages over a circuit during a given period of time. Traffic also includes the relationship between Call attempts on traffic-sensitive equipment and the speed with which the calls are completed. Traffic analysis allows to determine the amount of bandwidth needed in a circuit for data and for voice calls. Traffic engineering addresses service issues by enabling us to define a Grade of Service or Blocking factor. A properly engineered network has low blocking and high circuit utilization, which means that service is increased and costs are reduced.

5.1.1. Factors:

There are many different factors that should be considered when analyzing traffic.
The most important factors are:

- **Traffic Load Measurement**
- **Grade of Service**
- **Traffic Types**
- **Sampling Methods**

Of course, other factors might affect the results of traffic analysis calculations, but these are the main ones. Assumptions can be made for other factors.

5.1.2. Traffic Load Measurement

Traffic load is the ratio of call arrivals in a specified period of time to the average amount of time taken to service each call during that period. These measurement units are based on Average Hold Time (AHT). AHT is the total time of all calls in a specified period divided by the number of calls in that period, as shown in the following example, where 23 Calls have a total duration of 3976 Seconds:

AHT = 3976 total call seconds) / (23 calls) = 172.87 Seconds

The two main measurement units used today to measure traffic load are Erlang and Centum Call Seconds (CCS). One Erlang is 3600 seconds of calls on the same circuit, or enough traffic load to keep one circuit busy for 1 hour. Traffic in Erlang is the product of the number of calls and AHT divided by 3600 i.e. {(Calls X AHT) / 3600} as shown in the following example:

(23 calls v 172.87 AHT) / 3600 = 1.104 Erlang

One CCS is 100 seconds of calls on the same circuit. Voice switches generally measure the amount of traffic in CCS. Traffic in CCS is the product of the Number of Calls and the AHT divided by 100 i.e. {(Calls X AHT) / 100} as shown in the following example:

(23 calls v 172.87 AHT)/100 = 39.76 CCS

Many switches use CCS because it is easier to work with increments of 100 rather than 3600. Both units are recognized standards in the field. The relation between the Erlang and CCS is:

1 Erlang = 36 CCS.

Traffic in Erlang = (Average Number of Calls C in Time T) X (Average Call Holding Time h)

A = (C X h) / T. T is 60 Minutes and h is in hours.

Example 1

On average, during the Busy Hour, a Company makes 120 Outgoing Calls of Average Duration of 2 Minutes. It receives 200 Incoming Calls of Average Duration of 3 Minutes. Find total Traffic handled.

Answer

Outgoing Traffic = (120 X 2) / 60 E = 4 Erlang. Incoming Traffic = (200 X 3) / 60 E = 10 Erlang.

Total Traffic is 14 Erlang.

5.1.3. Busy Hour Traffic

We commonly measure network traffic load during the busiest Hour because this period represents the maximum traffic load that the network must support. The result gives a traffic load measurement commonly referred to as the Busy Hour Traffic (BHT). There are times when we cannot do a thorough sampling or we have only an estimate of how many calls we are handling daily. In such a circumstance, we can usually make assumptions about the environment, e.g. average number of calls per day and the AHT. In the standard business environment, the busy hour of any given day accounts for approximately 15 to 20 % of the Traffic for that day. We generally use 17 % of the Total daily traffic to represent the peak hour traffic. In many business environments, an acceptable AHT is generally assumed to be 180 to 210 seconds. We can use these estimates to determine trunking requirements without having more complete data.

5.2. Grade of Service

Grade of Service (GOS) is defined as the Probability that Calls will be blocked while attempting to seize circuits. It is written as P.xx blocking factor or blockage, where xx is the percentage of Calls that are blocked for a traffic system. For example, traffic facilities requiring P.01 GoS define a 1 percent probability of callers being blocked to the facilities. A GoS of P.00 is rarely requested and will rarely happen because to be 100 percent sure that there is no blocking, we would have to design a network where the caller to circuit ratio is 1:1. Also, most traffic formulas assume that there are an infinite number of callers.

Example 2

During the Busy Hour, 1200 Calls are offered to a Group of Trunks and 6 Calls are lost. Average Call Duration is 3 Minutes. Find the Traffic carried and Congestion Period.

Answer

Number of Lost Calls = 6. So, Successful Calls = (1200 – 6) = 1194.
Traffic Carried = (1194 X 3) / 60 Erlang = 59.7 Erlang.
Grade of Service = 6 / 1200 = .005
So, Congestion Period = .005 X 3600 sec = 18 sec.

Example 3

During Busy Hour, Number of Busy Lines at an interval of 5 Minutes are: 12, 11, 13, 8, 10, 14, 12, 7, 9, 15, 17 and 16. Find out the Traffic Carried.

Answer

Traffic Carried = (12 + 11 + 13 + 8 + 10 + 14 + 12 + 7 + 9 + 15 + 17 + 16) / 12 Erlang
= 12 Erlang.

Example 4

A single Customer makes 11 Calls during 0900 to 1700 Hours. The Call durations are 3, 5, 10, 7, 10, 5, 1 5, 15, 34 and 5 Minutes respectively. Find the Average and busy hour Traffic Intensity, if only the last two calls are made during Busy Hour.

Answer

Total Call Duration = (3 + 5 + 10 + 7 + 10 + 5 + 1 + 5 + 15 + 34 + 5) Minutes = 100 Minutes

So, Average Holding Time / Call = 100 / 11 Minutes and Call Arrival Ratio = 11 / 8 Calls / Hr.

$$\text{Average Traffic / Hour} = \frac{(100 \text{ X } 11) / 8}{(11 \text{ X } 60)} \text{ Erlang} = 0.\ 208 \text{ Erlang}$$

During Busy Hour there are 2 Calls and the Total Duration for the Calls = (34 + 5) Minutes = 39 Minutes

So, Average Call Holding Time = 39 / (2 X 60) Hr = 0. 325 Hr.

Traffic Intensity during Busy Hour = 2 X 0, 325 Erlang = 0. 65 Erlang.

5.3. Traffic Types

We can use the telecommunications equipment that is offering the traffic to record the data described. Unfortunately, most of the samples received are based on the carried traffic on the system and not the offered traffic load. Carried traffic is the traffic that is actually serviced by telecommunications equipment. Offered traffic is the actual amount of traffic attempts on a system. Note that the difference in the two can cause some inaccuracies in our calculation.

The greater the amount of blockage we have, the greater the difference between carried and offered load. We can use the following formula to calculate offered load from carried load:

Offered load = Carried load / (1 – Blocking factor)

Unfortunately, this formula does not take into account any retries that might happen when a caller is blocked. We can use the following formula to take the retry rate into account:

Offered load = Carried load v Offered Load Adjustment Factors (OAF).

OAF = [1.0 – (R v Blocking factor)] / (1.0 – Blocking factor), where R is a percentage of retry probability. For example, R = 0.6 for a 60 percent retry rate.

5.4. Sampling Methods

The accuracy of any traffic analysis will also depend on the accuracy of our sampling methods. The following parameters will change the represented traffic load:

- Weekdays versus weekends
- Holidays
- Type of traffic (modem versus traditional voice)
- Apparent versus offered load
- Sample period
- Total number of samples taken
- Stability of the sample period

The ITU-T recommends that Public Switched Telephone Network (PSTN) connections measurement or read-out periods be 60 minutes and / or 15-minute intervals. These intervals are important because they let us summarize the Traffic Intensity over a period of time. If we take measurements throughout the day, we can find the Peak Hour of Traffic in any given day. There are two recommended ways to determine the peak daily traffic, as follows:

Daily Peak Period (DPP) records the highest traffic volume measured during a day. This method requires continuous measurement and is typically used in environments where the peak hour may be different from day to day. The example uses DPP to calculate total traffic load.

	Monday	Tuesday	Wednesday	Thursday	Friday	Total Load
Peak Traffic	12.7	12.2	12.5	12.2	12.3	61.9
Peak Time	9 AM	2 PM	10 AM	10 AM	11 AM	

Fixed Daily Measurement Interval (FDMI) requires measurements only during the predetermined peak periods. It is used when traffic patterns are somewhat predictable and peak periods occur at regular intervals. Business traffic usually peaks around 10:00 a.m. to 11:00 a.m. and 2:00 p.m. to 3:00 p.m. In the following example, using FDMI sampling, we see that the hour with the highest total traffic load is 10 a.m., with a total traffic load of 60.6 Erlang.

Hour	Monday	Tuesday	Wednesday	Thursday	Friday	Total Load
9 AM	12.7	11.5	10.8	11.0	8.6	54.6
10 AM	12.6	11.8	12.5	12.2	11.5	60.6
11 AM	11.1	11.3	11.6	12.0	12.3	58.3
12 PM	9.2	8.4	8.9	9.3	9.4	45.2
1 PM	10.1	10.3	10.2	10.6	9.8	51.0
2 PM	12.4	12.2	11.7	11.9	11.0	59.2
3 PM	9.8	11.2	12.6	10.5	11.6	55.7
4 PM	10.1	11.1	10.8	10.5	10.2	52.7

ITU-T Recommendation E.492 includes recommendations to determine the normal and high load traffic intensities for the month. As per ITU-T recommendation E.492, the normal load traffic intensity for the month is defined as the fourth highest daily peak traffic. If you select the second highest measurement for the month, it will result in the high load traffic intensity for the month. The result allows you to define expected monthly traffic load.

Considerations for Traffic Engineering

- Switches are administered based on Traffic Load / Average Busy Hour of the busiest Season.
- Office Busy Hour is used for Overall Administration, Engineering and Maintenance.
- Traffic Data is collected for One or Two Weeks on half-hourly basis during all parts of a Day, when the Loads are High.
- Trunk-Group Busy Hour is the time – consistent Hour, when the Maximum Trunk-group Load occurs.
- Traffic Data is collected for the Busy Hour in Months, likely to have Maximum Load.
- The Average Load for the Busy hour for a Business day in a Peak Season is the Average Busy Hour / Busy Season.
- Grade of Service (Lost Calls / Attempted Calls) must be as low as possible.

Call Arrival Patterns

The first step in choosing the proper traffic model is to determine the Call Arrival Pattern. Call arrival patterns are important in choosing a traffic model because different arrival patterns affect traffic facilities differently. The three main call arrival patterns are as follows and are described in the following sections:

- **Smooth Call Arrival Pattern**
- **Peaked Call Arrival Pattern**
- **Random Call Arrival Pattern**

A smooth traffic pattern occurs when there is not much variation in traffic. Call hold time and Call Inter-arrival times are predictable, allowing us to predict traffic in any given instance when there are a finite number of sources. For a smooth call arrival pattern, a graph of calls versus time might look like the as below in fig. 5.1.

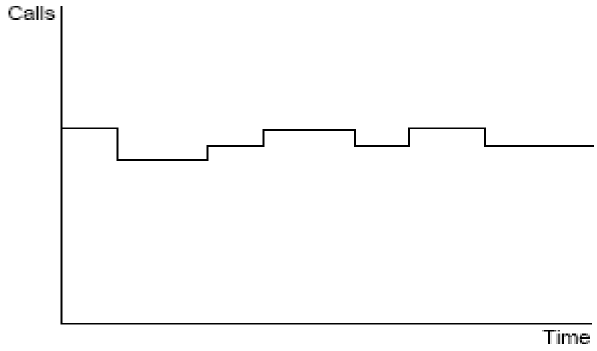


Fig. 5.1 Smooth Traffic Pattern

A peaked traffic pattern has big spikes in traffic from the mean. This call arrival pattern is also known as a hyper-exponential arrival pattern. There might be times when we would want to engineer rollover trunk groups to handle this kind of traffic pattern. In general, however, to handle this kind of traffic pattern we would need to allocate enough resources to handle the peak traffic. For example, to handle 30 calls all at once, we would need 30 trunks. A graph of calls versus time for a peaked call arrival pattern might look like as given in fig. 5.2

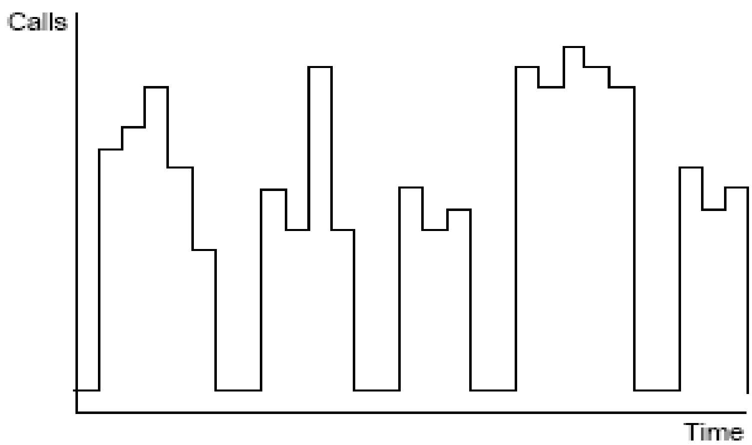


Fig. 5.2 Peaked Traffic Pattern

Random traffic patterns are exactly random. They are also known as Poisson or exponential distribution. Random traffic patterns occur in instances where there are many callers, each generating a little bit of traffic. We generally see this kind of random traffic pattern in private branch exchange (PBX) environments. The number of circuits that would be needed in this situation would vary from 1 to 30 circuits. A graph of calls versus time for a random call arrival pattern might look like as given in fig. 5.3.

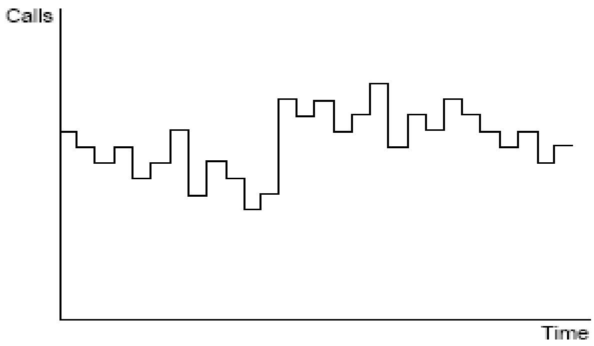


Fig. 5.3 Random traffic Pattern

5.5. Blocked Calls

A blocked call is a Call that is not serviced immediately. Calls are considered blocked if they are rerouted to another trunk group, placed in a queue, or played back a tone or announcement. The nature of the blocked call determines the model selected, because blocked calls result in differences in the traffic load. The main types of blocked calls are as follows:

Lost Calls Held (LCH) These blocked calls are lost, never to come back again. Originally LCH was based on the theory that all calls introduced to a traffic system were held for a finite amount of time. All calls include any of the calls that were blocked, which meant the calls were still held until time ran out for the call.

Lost Calls Cleared (LCC) These blocked calls are cleared from the system, meaning that when a caller is blocked, the call goes somewhere else (mainly to other traffic-sensitive facilities).

Lost Calls Delayed (LCD) These blocked calls remain on the system until facilities are available to service the call. LCD is used mainly in call center environments or with data circuits since the key factors for LCD would be delay in conjunction with traffic load.

Lost Calls Retried (LCR) LCR assumes that once a call is blocked, a percentage of the blocked callers retry and all other blocked callers retry until they are serviced. LCR is a derivative of the LCC model and is used in the Extended Erlang B model.

5.6. Probability in Telephone Traffic

In Telephone Exchange, Call Origination and Call Termination are Independent Random events. Following assumptions are needed for finding the Probabilities in Telephone Traffic.

- Each Attempted Call has a Probability of Success P and a Probability of Failure (1-A).
- The Result of each Call Attempt is an Independent Random Event.
- The Probabilities has a Statistical Equilibrium i.e. they do not change.
- The Probability of a particular combination of x Success and (N-x) Failures is

$$\mathbf{P^{x} \; X \; (1\text{-}P)^{n-x}.}$$

- If x is the Number of Calls arriving in Time T and μ is the Average Number of Calls in Time T, the Probability of Call Arrival

$$\mathbf{P(x) = (\mu^{x} / x\,!)\; e^{-\mu}\,.}$$

- Since Arrival and Termination of each Call are Independent Random Events, the Probability of Call duration being more than or equal to a given Time t s

$P(T \geq t) = e^{-t/h}$, where h is the Mean Holding Time.

Example 5

On average, one Call arrives every 5 Seconds. During a period of 10 Seconds, find the Probability of

No Call coming, One Call coming, Two Calls coming and more than Two Calls coming.

Answer

The Probabilities are:

a) No Call Arriving = $(2^{0} / 0\,!)$ X e^{-2} = e^{-2} = 0. 135
b) One Call Arriving = $(2^{1} / 1\,!)$ X e^{-2} = 2 X e^{-2} = 0. 27
c) Two Calls Arriving = $(2^{2} / 2\,!)$ X e^{-2} = 2 X e^{-2} = 0. 27
d) More than Two Calls Arriving = 1 – (0.135 + 0.27 + 0. 27) = 1- 0. 675 = 0. 325

Example 6

The Average call duration in an Exchange is 2 Minutes. A Call has already lasted 4 Minutes. Find the Probability of the Call lasting at least 4 Minutes more and Probability of the Call lending within the next 4 Minutes.

Answer

a) Probability of the Call lasting at least 4 Minutes is

$P(T \geq t) = e^{-t/h} = e^{-4/2} = e^{-2} = 0.135.$

b) Probability of the Call lending within the next 4 Minutes is

$P(T \leq t) = 1 - P(T \geq t) = 1 - 0.135 = 0.865$

5.7. Probability of Lost Calls

The Probability of Lost Calls are calculated by the method given below:

Let us consider a very small time δt, where the Probability of occurring of more than one Event is negligible. Then the Events can have the Probabilities ---

One Call arriving = P (a), **One Call ending = P (e)**

and **No Change in Call Status = [1- P(a) – P (e)]**

If the Mean Number of Calls arriving during Average Holding Time is A, then,

P (a) = (A X δt) / h

If there are K Calls in progress, **P (e) = (K X δt) / h.**

If the Probability of j Calls in progress at time t is P (j), then the Probability of Transition from j to k Busy States is

P (j to k) = P (j) X P (a) = P (j) X (A X δt) / h

If the Probability of k Calls in progress at time t is P (k), then the Probability of Transition from k to j Busy Trunks is

P (k to j) = P (k) X P (e) = P (k) X (K X δt) / h

But, P (j to k) = P (k to j). So, P (k) = (A / K) X P (j).

Thus, $P(1) = (A/1)\,P(0),\ P(2) = (A/2)\,P(1) = (A/2)(A/1)\,P(0) = (A^2/2!)\,P(0),$

$P(3) = (A/3)\,P(2) = (A/3)(A^2/2!)\,P(0) = (A^3/3!)\,P(0)$ **and so on.**

And the general form is $P(x) = (A^x / X!)\,P(0)$

Lost Call Assumption implies that any attempted Call, which encounters Congestion, is immediately cleared.

If the Number of Call Attempts is $0 \leq x \leq N$, where N is Number of Available Links,

$$\sum_{x=0}^{N} P(x) = \sum_{x=0}^{N} (A^x / X!)\,P(0).$$ **But, the L.H.S. is always equal to 1. This gives**

$$P(0) = \frac{1}{\sum_{x=0}^{N} (A^x / X!)\, P(0)} \quad \text{and}$$

$$P(x) = \frac{(A^x / X!)}{\sum_{x=0}^{N} (A^x / X!)\, P(0)}$$

P(x) is the Grade of Service and can be also denoted as $E_{1.N}$ (A). This is Erlang B Formula.

5.8. Erlang's Lost call Formula

Probability of Lost Calls depends on the Full Availability i.e., every Originating Call can be connected to any Free Outgoing Trunk and be Switched to the Terminating Line, if the later is free. The Lost Call Probability implies that whenever a Congestion is faced by the Attempted Call, the Subscriber is likely to have anew attempt to originate the Call. This results in increasing the volume of attempted Calls when there is Congestion.

The Probability of Congestion P(N) is the Grade of Service and is given by

$$E_{1.N-1} = \frac{A^{N-1}}{(N-1)!} \Big/ \sum_{x=0}^{N} (A^x / X!) \,.$$

So,

$$\sum_{x=0}^{N} (A^x / X!) = \frac{A^{N-1} / (N-1)!}{E_{1.N-1}(A)} + A^N / N! \quad \text{. This leads to}$$

$$E_{1.N}(A) = \frac{A\,[E_{1.N-1}(A)]}{N + A\,[E_{1.N-1}(A)]}$$

Example 7

A Group of 20 Trunks provides a Grade of Service of 0.01, when offered 12 Erlang Traffic.

a) How much is the improvement in Grade of Service, if One Extra Trunk is added?

b) How much does the Grade of Service suffer, if One Trunk is Out of Service from the Original Group?

Answer

a) Grade of Service can be found from Erlang's Lost Call Formula

$$E_{1.N}(A) = \frac{A\,[E_{1.N-1}(A)]}{N + A\,[E_{1.N-1}(A)]}$$

$$\text{So, } E_{1.21}(12) = \frac{12\,[E_{1.20}(12)]}{21 + 12\,[E_{1.20}(12)]} = \frac{12 \times 0.01}{21 + 12 \times 0.01} = \frac{0.12}{21.12} = 0.0057$$

$$\text{b)}\quad E_{1.20}(12) = \frac{12\,[E_{1.19}(12)]}{20 + 12\,[E_{1.19}(12)]}$$

$$\text{or } 0.01 = \frac{12\,[E_{1.19}(12)]}{20 + 12\,[E_{1.19}(12)]}$$

$$\text{or } 0.2 + 0.12\,[E_{1.19}(12)] = 12\,[E_{1.19}(12)]$$

$$\text{So, } [E_{1.19}(12)] = 0.2 / 11.88 = 0.017$$

5.9. Traffic Measurements needed in a Digital Exchange

Traffic Intensity for both Originating as well as Terminating Traffics must be measured and analyzed.

a) **Originating Traffic:**

- Number of Call Attempts
- Number of Call attempts resulting in Seize
- Number of Answered calls
- Number of Invalid calls due to
    1. No Dialing

2. Incomplete Dialing
3. Invalid Number Dialing

- Blocking through the Switching Network
- Unavailability of Common Resources (Congestion)
- System Faults

b) Terminating Traffic:

- Number of Attempted Calls
- Number of Answered Calls
- Number of Calls not routed due to Exchange
- Number of Calls not routed due to Subscriber

1. Busy
2. No Response
3. Restricted Class of Service.
4.

5.10. Traffic Administration In C-Dot 128 P RAX

In regard to C-DOT 128P RAX the traffic administration function and services are available to the maintenance supervisor with the entry of Traffic command. Once this mode is entered, the supervisor should use the following sub – commands to get the various traffic data.

1 - call attempts
2 - intra exchange answered calls
3 - congestion in direction 0, X, 9
5 - outgoing calls in direction 0, X, 9
6 - incoming calls from direction 0, X, 9
7 - calls abandoned without dialing
8 - calls abandoned due to incomplete dialing
9 - calls abandoned due to invalid number dialing

The duration for which the detailed traffic to be recorded is however entered.