1. **How are switching systems classified? In what way is stored program control (SPC) superior to hardwired control?**

![Diagram of switching systems]

**ELECTRO MECHANICAL SWITCHING SYSTEM**
- Limited capability
- Virtually impossible to modify them to provide additional functionalities.

1. **STROWGER/ STEP BY STEP SYSTEM**
   - Control functions are performed by circuits associated with the switching elements in the system.

2. **CROSSBAR SYSTEM**
   - Have hard-wired control sub-systems which use relays and latches.

**ELECTRONIC SWITCHING SYSTEMS**
- Control functions are performed by a computer or a processor;
- Also called stored program control (SPC) system.

1. **SPACE DIVISION SWITCHING**
   - A dedicated path is established between the calling and the called subscriber for the entire duration of the call.
   - Technique used in Strowger and crossbar systems.

2. **TIME DIVISION SWITCHING**
   - Sampled values of speech signals are transferred at fixed intervals; May be analog or digital.
     
     A. **ANALOG SWITCHING** - The sampled voltage levels are transmitted as they are.
     B. **DIGITAL SWITCHING** - The sampled voltage levels are binary and transmitted.

     - **SPACE SWITCHING** - If the coded values are transferred during the same time interval from input to output.
• TIME SWITCHING - If the values are stored and transferred to the output at a later time interval.
• COMBINATION SWITCHING - Combination of time and space switching.

<table>
<thead>
<tr>
<th>STORED PROGRAM CONTROL</th>
<th>HARDWIRED CONTROL</th>
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<tbody>
<tr>
<td>Features properties changed through programming,</td>
<td>It requires physical changes to wiring,</td>
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<tr>
<td>which can be done in PBX system remotely.</td>
<td>strapping etc which means it cannot be done remotely.</td>
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<tr>
<td>Do not require that much of space and do not</td>
<td>Equipments require more space &amp; constant adjustment</td>
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<tr>
<td>require constant adjustment and cleaning.</td>
<td>and cleaning.</td>
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<tr>
<td>Few techniques required to manage.</td>
<td>More number of techniques required to work</td>
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2. **What is side tone? Explain the working of anti-side tone circuit.**

• The speech of A is heard by B as well as in A’s own earphone. This audio signal, heard at the generating end, is called side tone.
• If no side tone is present, a person tends to shout and if too much of side tone is present; there is a tendency to reduce the speech to a very low level.
• Human speech and hearing system is a feedback system in which the volume of speech is automatically adjusted, based on the side tone heard by the ear.

**WORKING OF ANTI-SIDE TONE CIRCUIT**

• This circuit has small level of side tone and the full speech signal from the other party are coupled to the receiver.
• Impedance Zb is chosen to be more or less equal to the impedance seen by the circuit to the right of section AA1.
• As a consequence, with proper side tone coupling the speech signal from the microphone M divides more or less equally in the two windings P and Q.
• Since the signals in these two windings are in the opp. direction, only a small induced voltage appears in the receiver circuit providing the side tone.
• When a signal is received from the other entity, it travels in the same direction in both windings P and Q, inducing a large signal in the receiver circuit.

![A telephone circuit with sidetone coupling.](Fig. 1.8)
3. **Explain the content of instantaneous current in microphone and flux in the earphone with suitable expressions.**

When the sound waves impinge on the diaphragm, the instantaneous resistance of the microphone is given by

\[ r_i = r_0 - r \sin \omega t \]

where

- \( r_0 \) = quiescent resistance of the microphone when there is no speech signal
- \( r \) = maximum variation in resistance offered by the carbon granules, \( r < r_0 \)
- \( r_i \) = instantaneous resistance.

Ignoring impedance external to the microphone in the circuit, without loss of generality, the instantaneous current in the microphone is given by

\[ i = V/(r_0 - r \sin \omega t) = I_0(1 - m \sin \omega t)^{-1} \]

where

- \( I_0 = V/r_0 \) = quiescent current in the microphone
- \( m = r/r_0 \), \( m < 1 \)

By binomial theorem, Eq. (1.3) may be expanded as

\[ i = I_0(1 + m \sin \omega t + m^2 \sin^2 \omega t + ...) \]

If the value of \( m \) is sufficiently small, which is usually the case in higher-order terms can be ignored in Eq. (1.4), giving thereby

\[ i = I_0(1 + m \sin \omega t) \]

which resembles the amplitude modulation (AM) equation. Thus,

Thus the carbon granule microphone acts as a modulator of the direct current \( I_0 \) (analogous to the carrier wave in AM system).

**The instantaneous flux linking the poles of the electro magnet and the diaphragm is given by**

\[ \phi_i = \phi_0 + \phi \sin \omega t \]
Equation 5 assumes that the vibrations of the diaphragm are too small to affect the length of the air gap and that the reluctance of the magnetic path is constant.

The instantaneous force exerted on the diaphragm is proportional to the square of the instantaneous flux linking the path.

We have thus seen that the force experienced by the diaphragm is in accordance with the signals produced by the microphone.

4. **Describe the switching networks configuration of a switching system.**

Switching system/ an exchange

- Major components: set of input and output circuits called inlets and outlets.
- Function: to establish an electrical path between a given inlet-outlet pair.
- Hardware used for establishing such a connection is called ‘Switching matrix’ or ‘Switching network’.
When $N=M$, the switching network is called a Symmetric network.

The inlets/outlets may be connected to local subscriber lines or to trunks from/to other exchanges.

Fig c **Folded Network**
- When all the inlets and outlets are connected to the subscriber lines, the logical connection appears as shown in the figure.
- In this case, the output lines are folded back to the input and hence the name.
- In a folded network with $N$ subscribers, there can be a max of $N/2$ simultaneous calls or info technologies.
Fig d **Non-folded Network**
- All the inlet/outlet connections may be useful for inter exchange transmission. In such a case, the exchange does not support local subscribers and is called a Transit exchange or non-folded network.
- In a non-folded network with $N$ inlets and $N$ outlets, $N$ simultaneous info transfers are possible.

5. A central battery exchange with 48V battery consists of carbon microphone with min of 24 MA energizing current. The battery resistance is $400 \, \Omega$ in series and a DC resistance of microphone is $50 \, \Omega$. If cable resistance is $50 \, \Omega / \text{km}$ find the max distance at which the subscribers station can be located.

6. **Explain with the aid of block diagram the elements of a switching system.**

- A switching system is composed of elements that perform switching, control and signalling functions.
- Subscriber lines are terminated at the subscribers line interface circuits, and trunks at the trunk interface circuits.
- Some service lines are used for maintenance and testing purpose.
- Junctors circuits imply a folded connection for the local subscriber and the service circuits.
- Line scanning units sense and obtain signaling info from the respective lines.
- Distributors units send out signaling info on the respective lines.
- Operator console permits interaction with the switching system for maintenance and administrative purposes.
- Direct control switching system – Control sub system is integral part of the switching network itself. Ex: Strowger exchange.
- Common control switching system/ Indirect control/ Register control- Control sub system is outside the switching network. Ex: Crossbar, Electronic exchange, SPC systems.

Switching Network
- Provides the switching paths.
- Doesn’t distinguish b/w inlets/ outlets that are connected to the subscribers/ trunks.

Control sub system
- Actually establishes the switching paths.
- Job is to distinguish b/w inlets/ outlets connected to the subscribers/ trunks and interpret correctly the signaling info received on these lines.
- After connection is established, based on the signaling info received on the inlet lines, it send out signaling info to the subscriber and other exchanges connected to the outgoing trunks.

7. Generalize the common control functions of a switching system with a diagram.

Common control functions in a switching system may be placed under 4 broad categories:
1. Event monitoring
2. Call processing
3. Charging
4. Operations and maintenance
• Events occurring outside the exchange at the line units, trunk junctors and inter exchange signaling receiver/sender units are all monitored by the control sub systems. Ex: Call request and call release signals at the line units.
• The occurrences of the events are signaled by operating relays which initiate control actions.
• When a subscriber goes off hook, the event is sensed, the calling location is determined, marked for dial tone and the register finder is activated to seize a free register.
• Identity of the calling lines is used to determine line category and the class of service to which the subscriber belongs.
• Initial translator determines the route for the call through the network and decides whether a call should be put through or not. Also, it determines the charging methods and the rates applicable to the subscriber.
• Based on the class of the service info of the subscriber- decision on call barring, call priority, call charging, origin based routing and no dialing calls are taken.
• If a call is destined to a no. in other exchange, the initial translator generates the reqd. routing digits and passes them to the register sender.
• Digits corresponding to the subscriber identification are concatenated and the combined digits pattern is transmitted over the trunks to the external exchange.
• Register sender uses appropriate signaling techniques, depending on the requirements of the destination exchange.
• If a call is destined to a subscriber within the same exchange, the digits are processed by the final translator.
• Final translator determines the line unit to which a call must be connected and the category of the called line.
• Important function of the common control subsystem- Controlling the operation of the switching network- done by making the switching elements at dif. Stages in accordance with a set of binary data defining the path and then commanding the actual connection of the path.
• Path finding may be carried out at the level of the common control unit (aka, map-in-memory) or the switching network (aka map-in-network).

Map-in-memory
• The control unit supplies the complete data defining the path
• Present in SPC subsystems

Map-in-network
• The control unit merely masks the inlet and outlet to be connected and the actual path is determined by the switching network.
• Common in crossbar exchanges using markers for control.

8. **Explain touch tone dial telephone and its design considerations against talk off.**

Rotary dial is replaced by a push button keyboard. Touching a button generates a tone which is a combination of 2 frequencies, one from the lower and the other from the upper band.

Advantages over rotary dial - Higher dialing rate; Potential for data transmission and remote control; End to end signaling only possible if the signaling is in the choice frequency band so that the signaling info can be transmitted to any point in the telephone network to which voice can be transmitted.
Rotary dial signaling is limited to 10 distinct signals, whereas a higher no. would enhance signaling capabilities significantly.

The need for touch tone signaling frequencies to be in the voice band brings with it problem of talk off which means that speech signals may be mistaken for touch tone signals and unwanted control actions such as terminating a call may occur.

Design considerations for touch tone signaling stem from the need for protection against talk off and include the following factors:

- Choice of code
- Band separation
- Choice of frequencies
- Choice of power levels
- Signaling duration

**Choice of Code**

- Should be such that imitation of code signals by speech and music should be difficult.
- Multi frequency code should be used; as simple signal frequency structures are prone to easy imitations as they occur frequently.
- Advantageous to keep fixed the no. of frequencies to be transmitted for any valid code word - leading to the considerations of P out of N code.
- Combination of P frequencies out of N frequencies constitutes code word. He code yields \( \frac{N!}{P!(N-P)!} \) Code words.

**Band separation**

- The chosen frequencies P and N are placed in separate bands and a restriction of one frequency from each band is chosen to form a code word.
- When multiple frequencies are present in speech signal, they are closely spaced.
- Band separation reduces the probability of speech being able to produce touch tone combinations.

**Advantages**

- Before attempting to determine the 2 specific frequencies at the receiver end, band filtering can be used to separate the frequency groups. This renders determination of specific frequencies simpler.
- Each frequency component can be amplitude regulated separately.
- Extreme instantaneous limiters which are capable of providing substantial guard action can be used for each frequency separately to reduce the probability of false responses to speech or other controlled signals.
Choice of frequencies
- Dictated by the attenuation and delay distortion characteristics of telephone network circuits for the voice band frequencies (300 Hz-3400 Hz).

Choice of power levels
- Desirable that the signal power be as large as possible.
- A nominal value of 1 db above 1 MW is provided for at the telephone set for the combined signal power of the 2 frequencies.
- The nominal output power levels have been chosen as -3.5 dbm and -0.5dbm for the lower and upper band frequencies respectively.
- Attenuation increases with frequencies.

Signaling duration
- Probability of talk off can be reduced by increasing the duration of the test applied to a signal by the receiver before accepting the signal as valid.
- A min. of 40ms has been chosen for both signal and inter signal intervals allowing for a dialing ate of over 10 signals per second.

9. **Explain the principle of cross bar switching with the diagram of 3x3 cross bar.**

![Diagram of 3x3 cross bar switching](image)

- Basic idea of cross bar switching is to provide a matrix of n x m sets of contacts with only n + m activators or less to select one of the n x m set of contacts.
- Aka co-ordinate switching as the switching contact is arranged in an x y plane.
- A set of vertical and horizontal contact points are connected to the array of horizontal and vertical wires (shown by solid lines).
- The contact point form pairs, each pairs consisting of a bank of 3 or 4 horizontal and a corresponding bank of vertical contact points.
- The contact point pair acts as a cross point switch and remains separated or open when not in use.
The contact points are mechanically mounted (and electrically insulated) on a set of horizontal and vertical bars (shown as dotted lines). The bars are in turn attached to a set of electro magnets.

When an electro magnet, say in horizontal direction is energized, the bar attached to it slightly rotates in such a way that the contact points attached to the bar move closer to its acing contact points but do not actually make any contact.

Now, if an electro magnet in the vertical direction is energized, the corresponding bar rotates causing the contact points at the intersection of the 2 bars to the close. This happens because, the contact points move towards each other.

Ex: If electro magnets M2 and M3 are energized, a contact is established at the cross point 6 such that the subscriber B is connected to the subscriber C.

**10. Why are blocking cross bars used in switch?**

The no. of vertical bars is less than the no. of subscribers and determines the no. of simultaneous calls that can be put through the switch.

- In a non-blocking cross bar configuration there are N2 switching elements for N subscribers. When all the subscribers are engaged only N 2 switches are actually used to establish connections. Providing N2 cross points even for moderate no. of users leas to impractical complex circuitry. Thus ways have to be found to reduce the no. of switch contacts for a given no of subscribers.
- The no. of cross point switches can be reduced significantly by designing blocking configurations (that may be single or multi stage switching network).
- The cross bar hardware may be reduced by connecting two subscribers to a single bar and letting the bar turn both in the clockwise and the anti-clock wise directions and this closing 2 diff. cross point contacts.
- With such an arrangement the no. of cross bar reduces but the no. of cross point switches remain the same.

Ex: consider 8 x 3 blocking cross bar switch.

- To establish a connection b/w subscribers A and B.
- Horizontal bar A is energized.
- One of the free vertical bars, say P, is energized.
- Cross point AP latches.
• Now if we energize the horizontal bar B, BP will not be latched, as the P verticals energized before B was energized.
• To connect A to B, we need another vertical cross bar which should electrically correspond to the vertical bar P.
• The bar P1 is associated with the same electrical wire as the bar P.
• When P1 is energized after B, the cross point BP1 is latched and a connection b/w A and B is established.

Summarize A-B circuit connection

Energize horizontal A
Energize free vertical P
De Energize horizontal A
Energize horizontal B
Energize Vertical P1
De Energize horizontal B

Thus we need to operate 4 cross bars to establish a connection. The no. of switches required is 2NK, where, N= No. of subscribers; K= No. of simultaneous circuits that can be supported.

11. Write a note on reed relay and giving the classification of cross point technology.

The hardware of the cross bar system predominantly consists of cross points switches.
• Cost of the system increases in direct proportion to the no. of cross points in the system.
• Focus-reduction of size and cost of a cross point.

**Electro mechanical cross point -2 types**

• Capable of switching (main/ breaking contacts) in 1-10 ms time duration and several million times without wear or adjustments.

**Mini switches**

• Made of precious metal like palladium which permits the designs of electrically quieter contacts.
• Corrosion resistance property of such metals and a bifurcated contact design have resulted in reliable switching in cross bar systems.
• Are mechanically attached –uses ‘V’ notches.
• Mounted on cross bars which move horizontally and vertically to establish and release contacts.
• Switching time 8-10 ms.

Reed Relay switches

• Eliminates the mechanical motion of bars in crossbar systems, thus increasing the operating life of system.
• Reed relay comprises of a pair of contacts made of a magnetic material sealed in a glass tube.
• Sealing protects the electrical contacts from external contamination.
• Displacement involved in making 2 contacts is about 0.2mm this results in fast switching time < 1 ms.
• May be latched electrically or magnetically.

• Glass tube is surrounded by a pair of coils and when current is passed through both coils simultaneously a field is created which causes the reed contacts to move together.
• When electrically latched, current is passed continuously through the coil as long as the switched connection is required.
• Magnetic latching relies on the hysteresis of the magnetic material.
• The pole pieces reqd. for this purpose may be placed outside the glass tube, or the contacts themselves may be designed to act as poles by choosing an appropriate ferro-magnetic material.
• The latter case, the reed relay is called ran reed signifying remnance property of the contact strips.
• The residual magnetism in the poles keeps the contacts closed even after the currents are withdrawn from the coils.
• When a demagnetizing current is applied to one or the other of the coils, the contacts open.
• With the advances in semi-conductor technologies, transistorized cross points were developed in 1960.
• Offered better performances than reed relay but were not economically competitive.
• With the advent of IC, many PABX were designed using IC cross points.

12. Brief about the organization of cross bar exchange.
Basic building blocks of crossbar exchange are:
Link frames - consists of a no. of cross bar switches arranged in 2 stages called primary and secondary with links b/w them.
The 2 stage arrangement with links has the effect of increasing the no. of outlets for a given no. of inlets, thereby providing greater selectivity. The switch, in this case, is said to be expanding.

Control markers

- Control the connections b/w the inlets and outlets via the primary section, links the secondary section.
- The line link frames along with the associated markers and registers are known as line unit and the trunk link frames with it is associated hardware as group unit.
- Trunk link frame may be sub divided into 2 or 3 link frames like local office link frames, incoming link frames etc.
- Line units are 2 way units-They can be used for originating as well as terminating calls.
- Because of its two way capabilities, the secondary section in the line link frame is called terminal section.
- The subscriber lines are terminated on the outlets of the terminal section frames.
- The group unit is a unidirectional device. It receives the calls from the line unit or from distant exchanges. It routes the calls to the unit of the same or distant exchanges. Capable of handling local, outgoing, incoming, terminating and transit calls.

CALL PROCESSING - Progresses in 3 stages:

1. Pre selection: performed by the originating marker, starts from the moment the subscriber lifts the handset of the telephone and ends when the dial tone is sent out to him by a register.
2. Group selection- The call is switched through the desired direction. The direction is decided in accordance with the code given by the translator.
3. Line selection: the calling subscriber is connected to the called subscribers by the terminating marker. The line of the called party is controlled by the terminating marker which also set up ringing on the line.