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GUIDANCE FOR STUDENTS

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CITY AND GUILDS OF LONDON INSTITUTE

Questions and Answers

Answers are occasionally omitted or reference is made to earlier Supplements in which questions of substantially the same form, together with the answers, have been published. Some answers contain more detail than would be expected from candidates under examination conditions.

ELEMENTARY TELECOMMUNICATION PRACTICE 1978

Students were expected to answer any 6 questions

Q1 (a) Describe, with a labelled sketch, the construction of a dry Leclanché-type cell.

(b) (i) In what important respect does a primary cell differ from a secondary cell?

(ii) Two identical new Leclanché cells are used to supply continuous currents of approximately 100 mA in one case, and 5 mA in the other. After a time it is noted that the voltage measured at the terminals of the cell delivering 100 mA has dropped from 1.5 V to 1.2 V but the other cell voltage still measures 1.5 V. Referring to the action of the cell, explain why these voltage changes have occurred.

A1 (a) The sketch shows the construction of a dry type of Leclanché cell. The zinc container forms the negative electrode, and the carbon rod the positive electrode. The exciting paste is a mixture of electrolyte (ammonium chloride) and a material to form a paste which will not interfere with the operation of the cell. Various manufacturers use different materials; for example, flour, sand (silicon dioxide), plaster of paris, or magnesium oxide. The depolarizer is a mixture of carbon and manganese dioxide made into a paste by the addition of ammonium-chloride solution. The container is covered with cardboard impregnated with paraffin wax. The carbon rod rests on a disc of insulating material to avoid contact with the zinc base. The space left above the paste is filled with wheat husks or ground cork which receives moisture and gas formed by the chemical action of the cell.

(b) (i) A primary cell differs from a secondary cell in that its chemicals are used up (that is, its chemical action is irreversible) whereas a secondary cell can be recharged (the original chemicals

reformed) by passing a current through it in the opposite direction to the discharge current.

(ii) When a cell is delivering current to a circuit, the chemical action produces hydrogen bubbles which collect at the carbon electrode, and these will insulate it from the electrolyte, thereby causing an increase in the internal resistance of the cell. This is known as *polarization* which is, in normal usage, overcome by the depolarizer oxidizing the hydrogen and forming water; as is the case for the cell supplying 5 mA.

In the case of the cell which is supplying 100 mA, the chemical action is producing hydrogen faster than it can be dispersed by the depolarizer. This causes the internal resistance to rise and thus the voltage drops to 1.2 V.

Q2 (a) Name the design of capacitor most suitable for EACH of the following applications. Give reasons for your choice, referring particularly to the properties of the dielectric material

(i) a 500 μF capacitor for smoothing a 50 V DC supply derived from AC mains, and

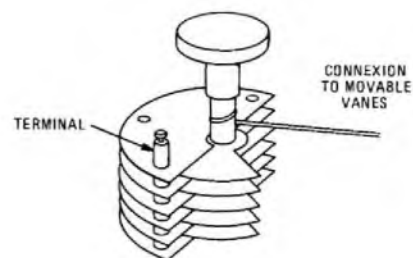
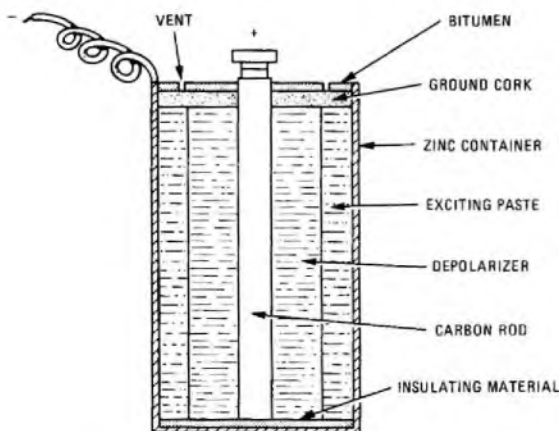
(ii) a 47 pF capacitor used in a radio receiver circuit to carry a signal of about 10 MHz.

(b) Describe, with a sketch, the construction of a variable capacitor, with air dielectric, for tuning a radio receiver.

A2 (a) (i) A dry-type electrolytic capacitor is the design which is most suitable for use as a smoothing capacitor for a 50 V DC supply derived from AC mains. The reasons are: that it is compact for its value since the dielectric is a thin oxide film formed electrolytically on its aluminium foil anode and that, because of the nature of the dielectric, it requires a DC polarizing potential which is available in a smoothing circuit such as that described.

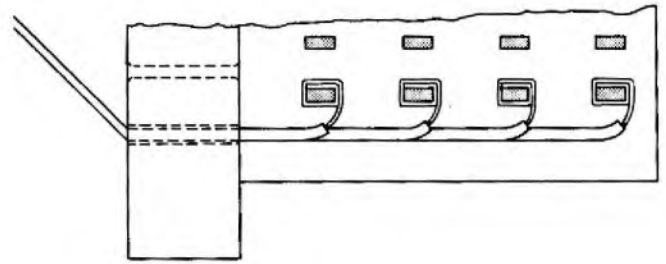
(ii) A silver mica or ceramic-type capacitor can be used as the most suitable in a radio receiver circuit to carry a 10 MHz signal. The reasons are: that mica and ceramic have a low loss at radio frequencies and their capacitances are stable. These capacitors are available within close tolerance limits, which is desirable at values such as 47 pF.

(b) The capacitor shown in the sketch consists of two sets of inter-



leaved parallel plates, referred to as *vanes*, one set being fixed and the other movable. The movable vanes are clamped between spacing washers and are attached to a control spindle mounted on bearings in the framework of the capacitor. The fixed vanes are riveted to two transverse bars and attached to the framework by ceramic insulating supports. Both sets of vanes are made of either aluminium or brass. The capacitance is varied by altering the overlap of the vanes, the maximum value of capacitance being obtained when they are fully meshed. A typical range of capacitance is from 10-500 pF and the capacitor is used for tuning a radio receiver.

Where it is required to vary the capacitance in more than one circuit at the same time (for example, in some designs of radio receiver) more than one capacitor may be *ganged* on a common spindle.



(b)

Q3 (a) Describe, with the aid of a table, how 20 pairs of an internal switchboard cable are identified. Indicate how the code is extended.

(b) Describe, with sketches, how such a cable is terminated on a tag block. Indicate how the wires are distributed from the cable onto the block and the method of terminating individual wires on the tags, noting any points requiring particular attention.

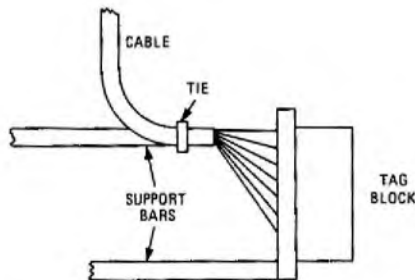
A3 (a) The table shows the identifying colour code on the insulation of the wires in an internal switchboard cable.

Pairs	B-wire	A-wire
1	Blue	White
2	Orange	"
3	Green	"
4	Brown	"
5	Grey	"
6	Blue	Red
7	Orange	"
8	Green	"
9	Brown	"
10	Grey	"
11	Blue	Black
12	Orange	"
13	Green	"
14	Brown	"
15	Grey	"
16	Blue	Yellow
17	Orange	"
18	Green	"
19	Brown	"
20	Grey	"

The code is extended by continuing the B-wire colours in the same sequence (blue, orange, green, brown, grey, for each 5 pairs and by using *white/blue* on all the A-wires of pairs 21-25, red/blue on pairs 26-30, and so on).

(b) Sketch (a) shows the method of fanning the pairs from the cable butt to the tag block. The cable is secured to the support bars by taping or tying, to ensure there is no movement, thus avoiding abrasion on the mounting ironwork. The pairs are threaded through the fanning holes and terminated either by soldered or wrapped connexions. Sketch (b) shows 4 tags prepared for soldering.

To make a soldered connexion: the insulation is stripped from the wire using the stripping tool; the wire and tag are checked to ensure that they are properly clean; 1½ turns of wire are tightly wrapped round the tag; using a hot tinned soldering iron making contact with the wire and tag, the correct solder and flux are applied and, as the solder melts, the soldering iron is lifted sharply away; the soldered



(a)

connexion is inspected. To make a wrapped connexion: the tags are inspected to ensure that they are not deformed but are clean and sharp edged; using the correct wrapping tool, a minimum of 7 contiguous turns is tightly wound.

Q4 (a) (i) Explain the difference between the rating and fusing currents of a fuse.

(ii) Describe the factors that govern the time required for a fuse to operate. Which is the most important factor?

(b) Sketch an alarm-type fuse and describe its operation for protecting telephone exchange equipment.

A4 (a) (i) and (b) See A6, Elementary Telecommunication Practice 1974, Supplement, Vol. 68, p. 14, Apr. 1975.

(a) (ii) A fuse operates when the wire is heated to its melting point. The factors affecting the time to reach this temperature are the *rate of heat generation* which is proportional to I^2R , where I is the current and R is the resistance of the wire, and the *rate of heat loss* by conduction (to the terminal posts) and by convection or radiation (to the atmosphere). Cool air currents over the fuse will delay operation. The current, I , is generally the dominant factor.

Q5 (a) Explain what is meant by "signalling" in telecommunications with THREE simple examples.

(b) Describe EACH of the following and give an example of their use

- (i) the two-out-of-five code,
- (ii) the five unit code, and
- (iii) the Morse code.

A5 (a) Signalling as applied to telecommunications means the transfer of information between two points by electrical means. Typical examples are telephony speech, teleprinter signalling, audible and visual calling signals or alarms, control switching circuits.

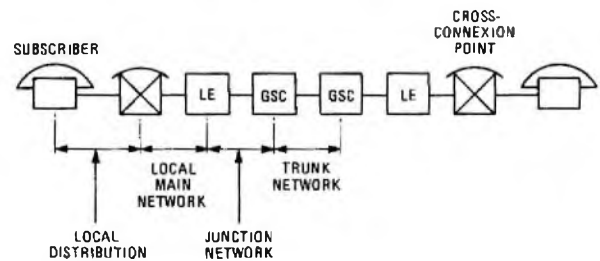
(b) See A9, Elementary Telecommunication Practice 1975, Supplement, Vol. 68, p. 88, Jan. 1976.

Q6 (a) (i) What is meant by the term "traffic" in telecommunications? (ii) Describe the basic differences between telephony and telegraphy.

(b) Describe, using a block diagram, how a long-distance telephone call would be routed between two subscribers, each on a local exchange, via trunk switching centres.

A6 (a) (i) Traffic in telecommunications is a measure of circuit or plant occupancy and is the product of the number and duration of calls over a certain period. The *erlang* is the unit of traffic. Traffic, in erlangs, is the product of the number of calls and the duration (in hours).

(ii) See A1, Elementary Telecommunication Practice 1971, Supplement, Vol. 64, p. 82, Jan. 1972.



LE: Local exchange
GSC: Group switching centre

(b) The sketch shows how 2 subscribers in different parts of the country may be interconnected through the telephone network. Each subscriber is connected to a local telephone exchange and between the local exchange and the subscriber are flexibility points known as *cross-connexion points*. These are normally *cabinets*. The local exchange is connected to the group switching centre for the area, and group switching centres are interconnected by the trunk network which includes the transit network. The actual routing and the number of exchanges used in the trunk network is usually dependent on the destination of the call and could include trunk cables and radio links. **NOTE:** The trunk network is to become known as the *main network*.

Q7 (a) Sketch a non-polarized telephone relay having one set of change-over contacts. Label the parts and show clearly the magnetic flux path.

(b) Explain how the performance of the relay would be affected if the residual air-gap was reduced.

(c) The core of a relay is wound with two identical coils. Compare, giving reasons, the forces exerted on the armature when the relay is connected to a 24 V supply

- (i) with the coils in parallel, and
- (ii) with the coils in series.

A7 (a) See sketch in A7, Elementary Telecommunications Practice 1972, Supplement, Vol. 68, p. 9, Apr. 1973.

(b) The residual stud, made of non-magnetic material, maintains the residual gap when the relay is operated. This prevents a closed magnetic circuit being formed and ensures the rapid release of the armature when the current ceases to flow. Thus, if the residual gap were reduced the armature would be slower to release.

(c) The force, F , exerted by each coil is proportional to the number of turns (N) and the current flowing in it.

(i) When the coils are in parallel, if R is the resistance of each coil, and a voltage, V , is applied across them, the current flowing in each coil is V/R .

$$\therefore F \propto \frac{NV}{R},$$

$$\text{and the total force} \propto \frac{2NV}{R}.$$

(ii) When the coils are connected in series, the total resistance is $2R$ and the current through each coil is $V/2R$.

$$\therefore F \propto \frac{NV}{2R},$$

$$\text{and the total force} \propto \frac{NV}{R}.$$

Therefore, the force exerted in case (i) is double that exerted in case (ii).

Q8 (a) Name the components numbered in Fig. 1.

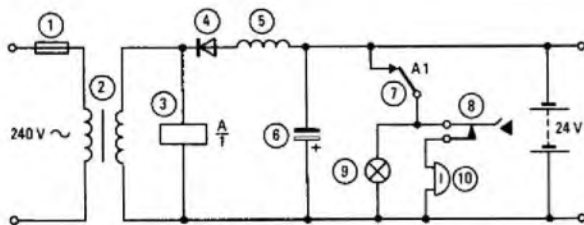
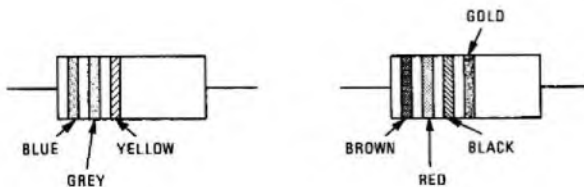


Fig. 1



(a)

(b)

Fig. 2

(b) (i) State the colour code used for marking resistors to indicate their values.

(ii) Give the values and tolerances of the resistors shown in Fig. 2.

A8 (a) The components shown in Fig. 1 are listed below.

- 1 Fuse.
- 2 Transformer with ferromagnetic core.
- 3 Relay coil.
- 4 Diode.
- 5 Choke winding (inductor).
- 6 Electrolytic capacitor.
- 7 Break contact unit.
- 8 Locking press-button with a break contact unit.
- 9 Signal lamp.
- 10 DC bell.

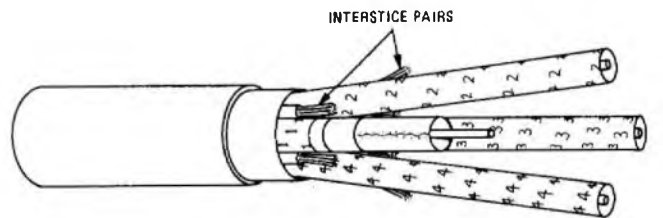
(b) (i) See A7, Elementary Telecommunications Practice 1975, Supplement, Vol. 68, p. 88, Jan. 1976.

(ii) Fig. 2(a)—Resistor shown is $680 \text{ k}\Omega$ and the tolerance is 20%.
Fig. 2(b)—Resistor shown is 12Ω and the tolerance is 5%.

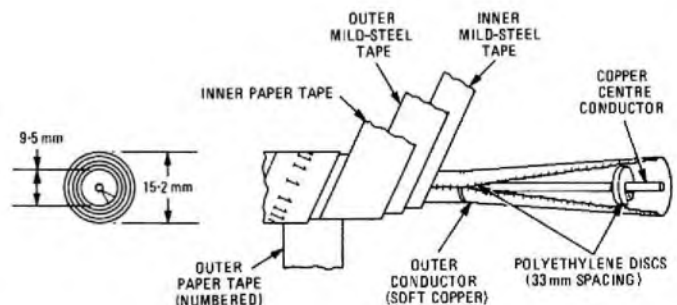
Q9 (a) Describe, with the aid of sketches, the construction of a four-pair coaxial underground cable.

(b) Compare in general terms a radio link and a coaxial cable link as a means of providing a large number of long-distance telephone circuits between exchanges.

A9 (a) The construction of a four $2.6/9.5$ coaxial pair cable with two 0.9 mm star-quad pairs and sixteen 0.9 mm twin pairs laid up in the spaces (interstices) between the coaxial pairs is shown in sketch (a). Each coaxial pair consists of a central copper conductor 2.6 mm in diameter centred, by means of polyethylene discs, in an outer tube with an internal diameter of 9.5 mm . The outer tube is formed from a single soft-copper strip with serrated edges and bound with two steel tapes and two paper tapes. The number of each coaxial pair is printed on the outer tape. Sketch (b) shows the detail of a typical $2.6/9.5\text{E}$ type coaxial pair.



(a)



(b)

(b) There are some features which are common to a radio link and a coaxial cable link. They both transmit a spectrum of frequencies, require separate *send* and *receive* paths and may also require intermediate amplifiers to overcome loss on the route.

The telephone speech channel used has a nominal bandwidth of 4 kHz , and these channels are superimposed on the wider *carrier* frequency spectrum at the sending end. At the receiving end the speech channels are selected by tuning, in the same manner as a normal radio receiver "tunes in" or selects stations.

There are features which are not common to both types of link.

A radio link requires line of sight between stations and can be

ELEMENTARY TELECOMMUNICATION PRACTICE 1978 (continued)

affected by rain or fog, whereas a coaxial cable link can be used between any two points and is unaffected by climatic conditions, but could be damaged mechanically. A radio link could be more practical or economic over difficult terrain.

- Q10** (a) Draw a labelled sketch of a moving-iron-diaphragm telephone receiver and explain its operation.
 (b) In such a receiver explain the effects of
 (i) replacing the permanent magnet with a similar piece of soft iron,
 (ii) short-circuiting one of the coils, and
 (iii) reversing the connexions to one of the coils.

A10 (a) See A1, Elementary Telecommunications Practice 1974, Supplement, Vol. 68, p. 12, Apr. 1975.

- (b) (i) The frequency of the incoming signal would be doubled and the sensitivity would be reduced. See the reference given in part (a) for a fuller explanation.
 (ii) Only one coil would be operative, therefore the signal would be weaker.
 (iii) If the connexions to one coil were reversed, then the flux due to each coil would cancel that of the other and there would be no audio output.

COMPUTERS B 1978

Students were expected to answer any 6 questions

- Q1** (a) What is meant by the terms binary-coded decimal and weighting?
 (b) State TWO advantages and TWO disadvantages of binary-coded-decimal representation.
 (c) Convert 6893_{10} into binary-coded-decimal form, weighted
 (i) 2421, and
 (ii) 5221.

A1 (a) Binary-coded decimal (BCD) is a system of writing numbers in such a way that each decimal digit is represented by a separate group of binary digits. Normally, BCD representation uses 4 binary digits to represent each decimal digit. Weighting is the process whereby each of these 4 binary digits is assigned a weight to obtain the desired properties of the code. The weights are chosen such that
 (i) their sums are not greater than 15,
 (ii) their sums are not less than 9,
 (iii) one of them must be a 1, and
 (iv) another of them must be either 1 or 2.

The decimal digit is then equal to the sum of the products of each BCD digit and its weight.

(b) BCD numbers can easily be converted to decimal form and vice versa. It is this property of BCD that provides its major advantages. The conversion is easy because each digit can be treated separately, without considering the other digits. This gives the advantages of easing the manual testing of computers and of simplifying the design of any hardware required to produce a decimal output from a binary input, because only 4 bit at a time need to be converted.

A disadvantage of BCD representation is that it is not the most efficient code for performing calculations. For this reason, pure binary or floating-point numbers are usually used in scientific applications. Another disadvantage is that BCD does not use all the possible permutations of the 4 binary digits making up the code. A 4-digit code, which has 16 different permutations, is used to represent only 10 different digits. Therefore, BCD is less efficient than pure binary code in its use of storage.

(c) (i) 6893_{10} has the following representation in BCD form, weighted 2421.

BCD:	0110	1110	1111	0011
Decimal:	6	8	9	3

(ii) 6893_{10} has the following representation in BCD form, weighted 5221.

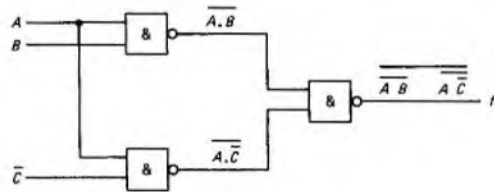
BCD:	1001	1011	1110	0011
Decimal:	6	8	9	3

- Q2** (a) Minimize the following Boolean expression:
 $f = A.B.C + A.C.D + A.B.D + A.B.C.D + A.B.C.D$
 (b) Draw a logic diagram, using NAND logic gates only, for the minimized function.

A2 (a) $f = ABC + ACD + ABD + ABCD + ABCD$
 $= A(BC + CD + BD + BCD + BCD)$, (distributivity)
 $= A(BC + D(C + B) + D(BC + BC))$, (distributivity)
 Now, if $F = DX + DY$, then when $D = 1$, $F = X$, and when $D = 0$, $F = Y$. Thus, $F = X + Y$.
 $\therefore f = A(BC + (C + B) + (BC + BC))$,
 $= A(BC + C + B + BC + BC)$, (associativity)
 $= A(C(B + 1) + B(1 + C) + BC)$, (distributivity)

$$\begin{aligned}
 &= A(C + B + BC), && \text{(identities)} \\
 &= A(C + (B + BC)), && \text{(associativity)} \\
 &= A(C + B + C), && \text{(identity)} \\
 &= A(B + C + C), && \text{(commutativity)} \\
 &= A(B + C), && \text{(identity)} \\
 &= AB + AC, && \text{(distributivity)} \\
 \text{(b) If } f &= AB + AC, \\
 \text{then } \bar{f} &= \overline{AB + AC}, \\
 &= \overline{AB} \cdot \overline{AC}, \\
 &= \overline{AB} \cdot \overline{AC}. && \text{(De Morgan)} \\
 \therefore f &= \overline{\overline{AB} \cdot \overline{AC}}.
 \end{aligned}$$

This expression contains only NAND functions, and a logic diagram using only NAND gates can be directly produced, as shown in the sketch.



- Q3** (a) Compare the characteristics of magnetic-tape and exchange-disc storage media with reference to access time, capacity, transfer rate, use and cost.
 (b) Show how the binary sequence 01 000 100 110 would be recorded on a magnetic surface using
 (i) a return-to-zero technique, and
 (ii) a non-return-to-zero technique.

A3 (a) (i) **Magnetic-Tape Storage**
Access time Information is stored on magnetic tape linearly along its length and, consequently, tape is a slow medium when a particular piece of information is to be retrieved: the tape must be wound to the required position. Access time can be anything from a few seconds if the tape is, by chance, positioned exactly as required, to many minutes if the tape has to be first located, loaded onto the tape-deck mechanism and then wound to the required position.
Capacity Reels of tape are removable, and this effectively creates an open-ended storage medium of unlimited capacity in an acceptable volume. A single reel of tape, with a storage density of about 63 bit/mm contains about 10 Mbyte of information.
Transfer rate The transfer rate of information to or from magnetic tape is dependent on the speed of movement of the tape relative to the READ/WRITE head. Typically, slow-moving tape runs at 635 mm/s, which creates a transfer-rate of 40 kbyte/s when information is stored at 63 bit/mm. Faster tapes move at 5.08 m/s; that is, a transfer rate of 320 kbyte/s.
Use Tape is used for the semi-permanent recording of bulk information (that is, information that can be erased when no longer required). A typical example is the retention of historical files of information such as personal records and monetary transactions. In

telecommunications, magnetic tape is used to record the charging of calls in stored-program-controlled switching systems. Tapes are periodically removed in order that the information stored upon them can be processed to produce statistics and customers' bills.

Cost The cost per bit of information stored on magnetic tape is very low, being typically 0.001p. Also, the information contained on the tape can be erased if no longer required and the tape re-used.

(ii) **Exchangeable-Disc Storage**

Access time Information is stored on magnetic discs on a series of concentric tracks. An actuating arm moves a READ/WRITE head to the desired track. In this form of storage, the disc can easily be removed in a protective plastic pack. The pack and its disc, known together as a *cartridge*, can be replaced in the disc unit when required. Access time is dependent on the mechanical movement of the head to the required track, and the waiting time until the continuously-revolving disc is in the appropriate position in relation to the head.

Typical head-movement delay is from approximately zero (if the head is positioned as required) to 60 ms, with an average delay of 20 ms due to the rotation of the disc.

Capacity Each magnetic disc offers a large but limited capacity whereby any piece of data or information can be randomly accessed, as explained above, in fractions of a second. The capacity of a single disc is typically 2-10 Mbyte. Packs, which contain a number of discs on the same spindle, can have capacities of 100-200 Mbyte. Disc-pack devices offer bulk-storage facilities somewhere between those of fast random-access storage (e.g., drums) and magnetic-tape storage.

Transfer rate The transfer rate of disc storage again depends on the speed at which the magnetic medium (the disc) passes the READ/WRITE head. A rate of 400 kbyte/s is typical.

Use The ease with which exchangeable discs can be removed and replaced makes them an ideal medium for increasing the security of a computer system. The disc, containing a copy of vital information about the state of the system, is periodically removed and replaced by another disc. Should the information be lost or corrupted within the system, it is possible to replace the disc and renew the information. Exchangeable discs are also used as a convenient means of transferring software (programs and data) to a system, particularly during the starting-up of the system.

Cost The cost per bit of information stored on exchangeable discs is more than for magnetic tape, but is still relatively cheap. The cost of a disc pack is equivalent to that of 4 or 5 tape reels, each having a larger capacity than the disc. Also, the drive mechanism is more costly to purchase and maintain.

(b) See A8, Computers B 1976, *Supplement*, Vol. 70, p. 44, July 1977.

Q4 (a) Draw a circuit diagram of a two-input diode-transistor positive-logic NAND gate with an emitter-follower output stage, and explain both its logical and electrical operation.

(b) Sketch, on the same voltage/time axes, a typical input and output voltage waveform for the emitter follower in part (a) above.

(c) State the reason for using the emitter follower.

A4 (a) See A10, Computers A 1977, *Supplement*, Vol. 71, p. 19, Apr. 1978.

(b) The output waveform is a replica of the input waveform, though its amplitude is reduced by a small amount equal to the base-emitter voltage of the emitter follower.

(c) See A4, Computers B 1974, *Supplement*, Vol. 68, p. 47, July 1975.

Q5 (a) With the aid of a suitable diagram, explain the meaning of the following terms in connexion with transistor logic elements:

- (i) saturation, and
- (ii) hole-storage time.

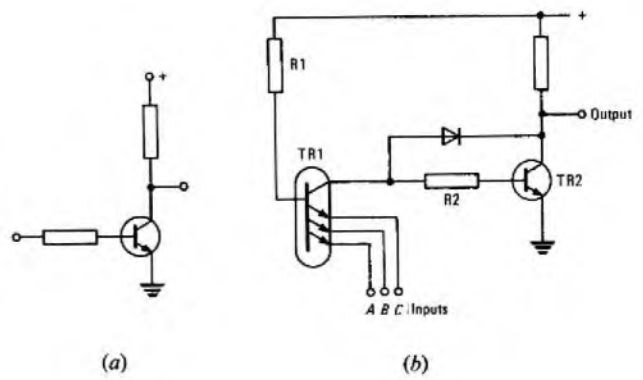
(b) Draw a circuit diagram of a typical three-input positive-logic transistor-transistor-logic (TTL) NAND element, explaining clearly the method used to overcome the effects of saturation.

A5 (a) (i) Saturation

Sketch (a) depicts a resistor-transistor logic gate.

When a positive voltage is applied to the base of the transistor, the transistor is turned on and current flows from the collector to the emitter. As the base voltage increases, the current increases until the transistor is fully turned on. A transistor is said to be *bottomed* when the base current is just sufficient to keep the transistor in its fully-conducting state, and the collector current is limited only by the external load. Any increase in base current beyond that required for bottoming will produce no further increase in collector current. This is the ideal condition for the ON state of a transistor switch.

If the base current exceeds the bottoming value, the base-emitter



voltage becomes greater than the collector-emitter voltage, and both junctions in the transistor become forward-biased. In this condition, the emitter injects more current carriers into the base region than are required to maintain full conduction, and the transistor is said to be saturated.

(ii) **Hole-Storage Time**

The excess current carriers in the base of a saturated transistor cause the base region to take on a stored charge in the same way as does a capacitor. If the base current of a saturated transistor is suddenly reversed, a delay occurs before the collector current begins to fall. This delay is called the *hole-storage time*, and is due to the excess carriers present in the base region tending to maintain the collector current. The collector current will not start to fall until the stored charge has been dissipated by recombination in the base, and by discharge through the base circuit.

Storage time depends upon the degree of saturation and the length of time spent in saturation. Hole storage has an important effect on the switching time of the transistor.

(b) The circuit diagram of a 3-input positive-logic TTL NAND element is shown in sketch (b). Transistor TR1 is a multiple-emitter transistor.

If the inputs A, B and C are at zero volts or are negative, transistor TR1 will be forward-biased and will draw current through R1. The voltage at the base of TR2 will therefore be almost zero, which is insufficient to switch on TR2.

If any of inputs A, B or C is at zero volts while the other inputs are at a high positive potential, then TR1 will still be forward-biased, and the potential at the base of TR2 will still not be sufficient to turn it on.

If high positive voltages are applied to A, B and C together, then the emitter-base junctions are reverse-biased and the collector-base junction is forward-biased, thus feeding current to the base of TR2. Thus, the voltage at the base of TR2 will rise and TR2 will turn on. The potential difference between the collector and emitter is almost zero, and the output potential is virtually zero (that is, the output is low-level).

If the low level is defined as logic state 0 and the high level as logic 1 (i.e., assuming the positive-logic convention), the operation of the gate is given by the following truth table.

Input			Output
A	B	C	
1	1	1	0
1	1	0	1
1	0	1	1
1	0	0	1
0	1	1	1
0	1	0	1
0	0	1	1
0	0	0	1

The circuit is therefore a NAND logic element. The effects of saturation are overcome by incorporating a clamping diode in the circuit. The clamping diode provides a feedback path from the collector of TR2 to the base. When the transistor is bottomed, the collector potential approaches the emitter potential, and the diode becomes forward-biased. Excess drive current is diverted via the diode and the emitter-collector path of the switched-on transistor. R2 is arranged to have a slightly larger voltage drop than the forward voltage drop of the diode and, therefore, the base-collector junction cannot become forward-biased. This prevents the transistor from saturating.

Q6 (a) Draw a block diagram of a typical modern digital computer, showing the main registers and their interconnection.

(b) Using the diagram drawn for part (a), explain the sequence of operations and flow of information for a JUMP (branch) instruction.

A6 See A6, Computers B 1972, Supplement, Vol. 66, p. 65, Oct. 1973.

Q7 (a) With the aid of suitable examples, explain the meaning of the following addressing methods, which may be used in digital computers:

- (i) direct,
- (ii) indirect, and
- (iii) modified (indexed).

(b) What is meant by the term literal addressing?

A7 (a) A digital computer has main storage for holding programs which control the sequence of operations made by the central processing unit (CPU), and data which is operated on by the CPU in accordance with the programs. In logical terms, the main store can be regarded as a series of consecutive locations, each of which is able to contain an instruction or data. The design of the computer determines the maximum number of locations (and their size) that can be individually addressed, and thus manipulated, by the CPU. The computer design also determines how the addressing methods are carried out by the CPU. The addressing methods listed in the question are available to the programmer when using an assembler language.

An assembler language can contain all 3 methods of addressing: direct, indirect and modified. In some instances, these methods can be used to influence each other. Taken in isolation, however, the addressing methods can be described as set out below.

(i) Direct Addressing

For direct addressing, the address in an instruction specifies an absolute location in the main store. The term *absolute* indicates a value from zero to the maximum number of locations in the main store. Sketch (a) shows an instruction to the CPU which contains an absolute address to address *directly* a location in the main store. The operation code could, for example, inform the CPU to add 1 to the content of location 2018.

(ii) Indirect Addressing

For indirect addressing, the address in an instruction specifies a location in the main store, as for direct addressing. However, as shown in sketch (b), one field of the instruction contains a bit designated *I*, which, when set, indicates to the CPU that indirect addressing is to take place. If, for example, the operation code is add 1 to the store location, and the indirect bit is set, then the CPU uses the address (2018) in the instruction to find the actual address (say, 10 094) of the value to be operated on. Thus, it is the content of store location 10 094 which is incremented by one.

This permits powerful operations to take place because the address in the instruction does not have to be altered to point to other locations. In sketch (b), location 2018 could be in a working area, and its content could therefore be altered by other programs without fear of corrupting the original instruction, which *indirectly* adds 1 to the location given at address 2018.

Indirect addressing can proceed through a number of levels, as shown in sketch (c).

(iii) Modified (or Indexed) Addressing

In this form, the address in an instruction specifies a location in the main store, as for direct addressing. Sketch (d) shows that one field of the instruction contains bit *X*, which, when set, indicates to the CPU that *modified* addressing is to take place. If the operation is to add 1 to the store location, and bit *X* is set, then the CPU uses the address (2018) in the instruction, modified by another value, to find the location in the main store where the content is to be incremented by one. The modifying value is contained in a specific location known to the CPU, and usually, for speed of operation, this location is a register known generally as the *X* (INDEX) register, rather than a location in the main store.

Thus, the content of the *X*-register may be quickly changed for access to an array, where the address in the instruction is the base address (start) of the array, and the content of the *X*-register is a pointer down the array.

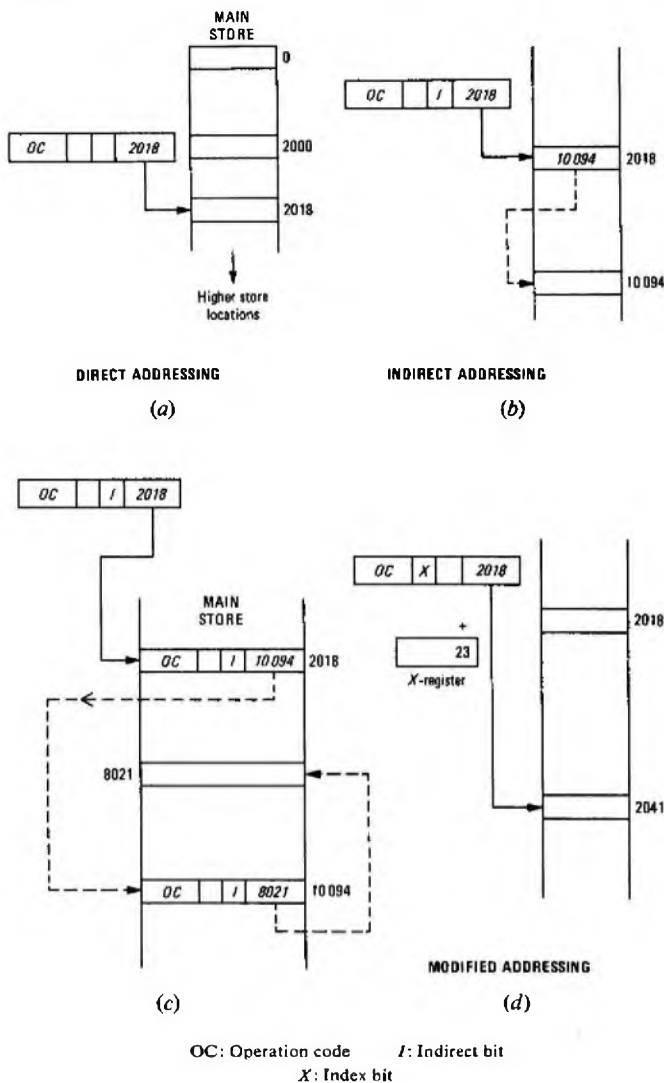
(b) Literal Addressing

Instructions in programs contain several fields, one of which can contain an address of a location in the main store. The instruction can also contain a *literal* bit which, if set, changes the meaning of the address field to the CPU. If the *literal* bit is set, then the CPU treats the content of the address field in the instruction as a data value rather than as an address.

Typically, the program instruction

ADD R3, 2018

means add the content of the store location 2018 to the content of register 3.



However, the instruction

ADD R3, "81"

means add the literal value 81 to the content of register 3, the inverted commas indicating that 81 is a literal value, and that the literal bit in the instruction is set.

Q8 (a) Sketch a graph of the possible signals on a typical ferrite-core-store READ wire during a complete READ/WRITE cycle. Draw on the same axes the signals for both states 1 and 0, with typical and extreme values.

(b) With the aid of a block diagram, explain the operation of the major sectors of a circuit which will accept the SENSE-wire output, amplify it, discriminate between states 1 and 0, and produce a READ output.

Q9 (a) Why are diode function-generators required in analogue computers?

(b) With the aid of a circuit diagram, explain the operation of a diode function-generator element for both positive and negative values.

(c) Plot the curve $y = x^2$, where x varies between ± 4 . Sketch the output of a typical diode function-generator on the same axes, and explain why the curves would be expected to differ.

A9 See A9, Computer B 1975, Supplement, Vol. 69, p. 55, Oct. 1976, and A8, Computers B 1973, Supplement, Vol. 67, p. 56, Oct. 1974.

Q10 (a) In the circuit shown in Fig. 1, *A* is a high-gain DC amplifier. Determine the sign and the magnitude of the output voltage, stating any assumptions made.

(b) Describe, with the aid of a suitable diagram, how the following may be obtained using a high-gain DC amplifier:

- (i) multiplication by a constant coefficient, and
- (ii) integration.

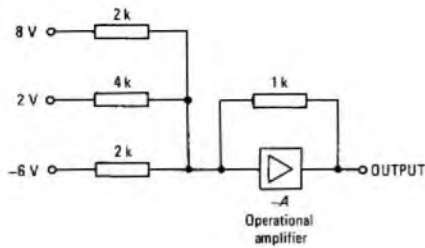


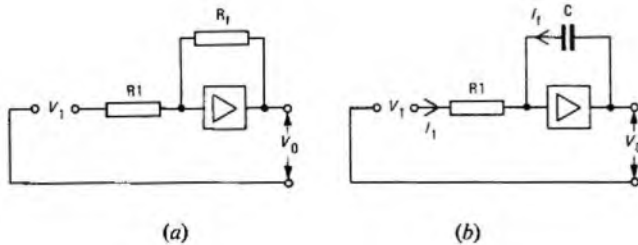
Fig. 1

A10 (a) For an analysis from first principles of the network in Fig. 1, see A8, Computers B 1975, Supplement, Vol. 69, p. 54, Oct. 1976. The analysis yields the equation

$$y = - \left(\frac{x_1}{R_1} + \frac{x_2}{R_2} + \frac{x_3}{R_3} \right) \times R_f$$

the minus sign arising from the 180° phase inversion of the operational amplifier. Substituting the given values gives the output voltage as

$$- \left(\frac{8}{2000} + \frac{2}{4000} - \frac{6}{2000} \right) \times 1000 = -1.5 \text{ V.}$$



(b) (i) A circuit for multiplication by a constant coefficient is shown in sketch (a). This is basically the same as the circuit in part (a), but with only one input. Using the relationship derived for part (a), but for one input, the following relation is obtained:

$$V_0 = -R_f \left(\frac{V_1}{R_1} \right) = -V_1 \left(\frac{R_f}{R_1} \right).$$

By selecting resistors R_f and R_1 in the required ratio, the input voltage can be multiplied by any desired constant coefficient.

(ii) An operational amplifier connected as an integrator is shown in sketch (b). The feedback component is a capacitor, so that current flows only when the capacitor is charging or discharging. As the capacitor is charging, the current flow is large initially, and reduces exponentially. However the reversing property of the operational amplifier has the effect of keeping the rate of charge constant, thus maintaining a constant current flow in the capacitor. (As the voltage applied to the plate on the input side increases, so the opposite voltage at the output of the operational amplifier is applied to the other plate, thus keeping the rate of change of charge constant.)

The operation can be explained mathematically as follows.

If q is the charge on the capacitor at any instant, then

$$I_f = dq/dt.$$

But $q = V_0 C$, assuming the virtual-earth principle.

$$\therefore I_f = C dV_0/dt.$$

By Kirchhoff's first law,

$$I_1 = -I_f.$$

$$\therefore \frac{V_1}{R_1} = - \frac{C dV_0}{dt}.$$

$$\therefore \frac{dV_0}{dt} = - \frac{V_1}{CR_1}.$$

The value of V_0 at any instant is found by integrating this equation with respect to time:

$$V_0 = - \frac{1}{CR_1} \int V_1 dt.$$

This shows that the output voltage is proportional to the time integral of the input voltage.

BASIC MICROWAVE COMMUNICATION C 1978

Students were expected to answer any 6 questions

Q1 (a) State precisely what is meant by the power flux density of an electromagnetic wave propagated in free space. In what units is power flux density measured?

(b) For an electromagnetic wave, explain in detail why

(i) the electric component always meets a perfectly conducting surface at right angles, and

(ii) the magnetic component is always parallel to a perfectly conducting surface.

A1 (a) The power flux density, or Poynting's flux, of an electromagnetic wave propagated in free space is defined as the product of the electric and magnetic fields and is normal to the plane containing the fields. The power flux density is measured in watts/metre².

(b) (i) The electric field of an electromagnetic wave can never have a component parallel to a perfectly conducting surface because this would cause an infinite current to flow in the conductor. Any component of an incident field parallel to the surface of the conductor is cancelled by an equal and opposite component induced at the surface.

(ii) Because the magnetic-field component of an electromagnetic wave is always at right angles to the electric-field component and, from part (i), the electric-field component must always be normal to a perfectly conducting surface, it follows that the magnetic-field component must always be parallel to the surface.

Q2 A loss-free transmission line having a characteristic impedance 600 Ω is terminated in a 400 Ω resistive load across which the voltage is found to be 120 V.

(a) Draw FOUR phasor diagrams for the same instant of time to show the magnitudes and time relations of the following components

(i) forward and reflected voltage and current components at the load, and

(ii) forward and reflected voltage and current components at a distance l from the load.

(All phasor components should be clearly labelled and values should be shown. Indicate with O the origin of each diagram so that additive and opposing phasors can be clearly distinguished.)

(b) The section of line has a length 1.25λ . Determine

(i) the voltage that must be applied at the input to produce 120 V across the load, and

(ii) the input impedance of the section.

A2 (a) The voltage reflection coefficient, ρ , due to a resistive load R ohms terminating a loss-free transmission line of characteristic impedance Z_0 ohms is given by:

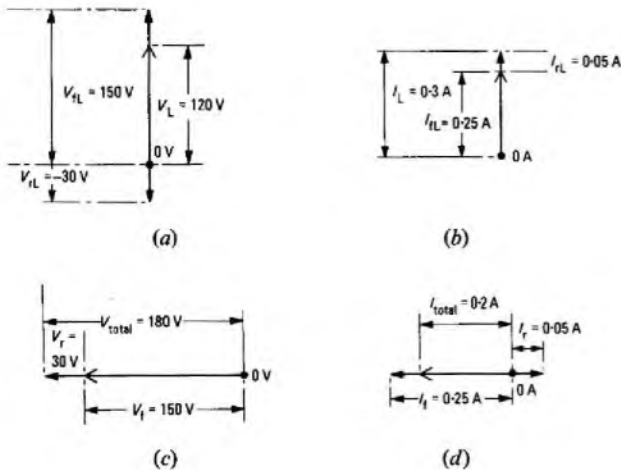
$$\rho = \frac{R - Z_0}{R + Z_0}.$$

(i) With $Z_0 = 600 \Omega$ and $R = 400 \Omega$, $\rho = -0.2$. Because ρ is negative, the forward and reflected voltages are in antiphase at the reference point; that is, the load R . This is represented by the phasor diagram shown in sketch (a).

But, $V_{rL} = \rho V_{fL}$ and $V_L = V_{fL} + V_{rL}$,

where V_{rL} is the reflected voltage at the load, V_{fL} is the forward voltage at the load, and V_L is the total voltage at the load.

$$\therefore V_{fL} = \frac{V_L}{1 + \rho} = \frac{120}{0.8} = 150 \text{ V and } V_{rL} = V_L - V_{fL} = -30 \text{ V.}$$



The current I_{fL} at the load due to the forward voltage is in phase with this voltage, and the reflected current I_{rL} at the load is in anti-phase with the reflected voltage. Therefore, the phasor diagram for the currents at the load is as shown in sketch (b).

But, $I_{rL} = -\rho I_{fL}$ and $I_L = I_{fL} + I_{rL}$,

where I_{rL} is the reflected current at the load, I_{fL} is the forward current at the load, and I_L is the total current at the load.

The total current flowing in the load is given by

$$I_L = \frac{V_L}{R} = \frac{120}{400} = 0.3 \text{ A, and } I_{fL} = \frac{I_L}{1 - \rho} = \frac{0.3}{1 - 2} = 0.25 \text{ A.}$$

(ii) At a distance $\lambda/4$ from the load, the phasor diagrams of forward and reflected voltages are as shown in sketch (c) and the corresponding diagrams for the currents are shown in sketch (d).

(b) (i) The voltages and currents on a loss-free line at a point 1.25λ from the resistive load are the same as those 0.25λ from the load. However, the voltage applied at any point on the line to produce 120 V at the load will always be the forward voltage (V_f) calculated in part (a); that is, 150 V.

(ii) The total current at a point 1.25λ from the load is the same as that shown in sketch (d); that is, 0.2 A. The input impedance of the 1.25λ -long section of line is therefore $180 \text{ V}/0.2 \text{ A}$; that is 900 Ω .

Q3 (a) Explain why the Q-factor of a resonant cavity is related to its surface area and its volume.

(b) On a diagram of the cross-section of the resonator of a reflex klystron indicate the pattern of the E-lines.

(c) Explain the influence of the value of the Q-factor of a reflex klystron resonator on

- (i) the available power output in the fundamental mode, and
- (ii) the ability to generate higher-order modes.

Q4 (a) Fig. 1 below shows a rectangular waveguide having a cross-section $4.8 \times 2.4 \text{ cm}$ and a short-circuit termination at ABCD. The waveguide is energized at 4.69 GHz in the dominant mode.

- (i) Calculate the guide wavelength.
- (ii) Copy Fig. 1 and indicate clearly, showing the appropriate distance from the termination, the position of a probe for strong excitation at this frequency.

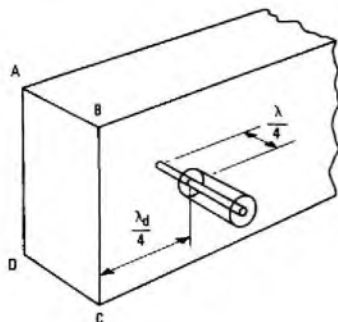


Fig. 1

(b) Waveguides having a broad dimension a should be energized by sources having λ between $1.07a$ and $1.60a$ where λ is the free-space wavelength. State the disadvantages of energizing at the frequency for which

- (i) $\lambda = 0.9a$, and (ii) $\lambda = 1.8a$.

A4 (a) (i) Guide wavelength and free-space wavelength are related by

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda^2} - \frac{1}{\lambda_c^2}$$

where λ_g is the guide wavelength, λ is the free-space wavelength, and λ_c is the cut-off wavelength.

For the dominant mode in rectangular waveguide, $\lambda_c = 2a$, where a is the dimension perpendicular to the electric field and is usually the broad dimension. At a frequency of 4.69 GHz, $\lambda = 6.40 \text{ cm}$.

$$\therefore \frac{1}{\lambda_g^2} = \frac{1}{6.4^2} - \frac{1}{9.6^2}$$

$$\therefore \frac{1}{\lambda_g^2} = \frac{1}{8.59^2}$$

$$\therefore \lambda_g = 8.59 \text{ cm.}$$

(ii) A probe transition to couple microwave energy into the dominant mode of rectangular waveguide has been added to Fig. 1. The probe functions as a coaxial quarter-wave aerial radiating into the waveguide. The inner conductor of the coaxial line extends approximately a quarter of a free-space wavelength into the waveguide, parallel to the electric field and is centrally placed to couple to the point of maximum field strength within the guide. To improve the match of the probe it may be surrounded by a cylinder of dielectric material. The probe is situated one quarter of a wavelength from the short-circuit termination at ABCD to ensure that energy radiated towards the short-circuit is returned in phase with the energy radiated from the probe in the forward direction.

(b) The dimensions of a rectangular waveguide are usually chosen to allow the propagation of the dominant waveguide mode only at the operating frequency; that is, the mode with the lowest cut-off frequency.

(i) If a waveguide is operated at a frequency such that the free-space wavelength, λ , is less than the broad dimension (that is, $\lambda = 0.9a$) the waveguide will be able to support an additional mode or modes (dependent upon the narrow dimension of the guide). This is undesirable because the different modes possess different propagation constants, which cause intermodulation distortion in frequency-modulated systems or errors in digital-modulation systems. Furthermore, the majority of standard waveguide components are designed for correct operation when only the dominant mode is present.

(ii) For a frequency such that the free-space wavelength approaches the cut-off wavelength of the dominant mode of the waveguide, the attenuation and dispersion (change of propagation constant with frequency) will be high.

This would cause distortion in frequency-modulated systems or errors in digital-modulation systems.

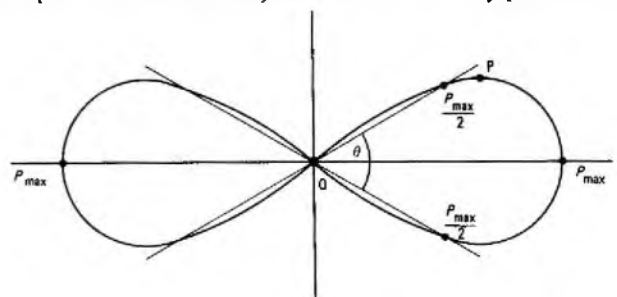
Q5 (a) A $\lambda/2$ dipole has a gain of 2.16 dB and a beamwidth of 78°. Explain with the aid of diagrams what is meant by these statements.

(b) Describe in detail the property of a paraboloidal surface that enables it to convert a spherical wave into a plane wave.

(c) State TWO disadvantages resulting from the presence of aerial side-lobes in EACH of the following cases

- (i) transmitting aerials for short-range, point-to-point microwave links, and
- (ii) receiving aerials for satellite-communication systems.

A5 (a) The sketch shows the E-plane power-radiation pattern of a $\lambda/2$ dipole. (The H-plane pattern is represented by a circle centred on the dipole and is not shown.) The distance from any point P on the



pattern to the origin O represents the relative strength of the radiation in the direction OP. The maximum radiation is in the direction OP_{max} . The aerial gain may be defined as the ratio of the radiation in this direction to that of an omnidirectional radiator. The beamwidth θ of the aerial is generally defined as the angle between the half-power points ($P_{max}/2$) on the radiation pattern.

(b) The important property of a paraboloidal surface is that the path lengths of rays from the focus to the surface and out to any plane parallel to the aperture of the paraboloid are the same. Thus, a spherical wave emitting from the focus is converted by the paraboloidal reflector into a plane wave propagating in a direction normal to the aperture.

(c) The following disadvantages result from the presence of side-lobes:

(i) For transmitting aerials for short range, point-to-point microwave links, the power radiated in the side-lobes detracts from the radiated power in the direction of the receiver. Radiation from the side-lobes of such aerials may also cause co-channel interference with other point-to-point links. Such interference may become severe under abnormal tropospheric propagation conditions (for example, ducting).

(ii) For receiving aerials for satellite-communication earth stations, the side-lobes may pick up unwanted noise radiated by surrounding objects. As in the previous case, the presence of large side-lobes will detract from the gain of earth station receiving aerials, particularly important with satellite communication systems which usually operate with small sensitivity margins.

Q6 (a) State the Sampling Theorem.

(b) A uniform train of square pulses of duration $2 \mu s$ recurring at intervals of $50 \mu s$ is amplitude modulated by a 5 kHz sinusoidal voltage. State which frequency components are present in the output waveform when this pulse train is applied to EACH of the following filters

- a low-pass filter with 4 kHz cut-off,
- a low-pass filter with 10 kHz cut-off,
- a filter with a pass band 12–18 kHz, and
- a low-pass filter with 28 kHz cut-off.

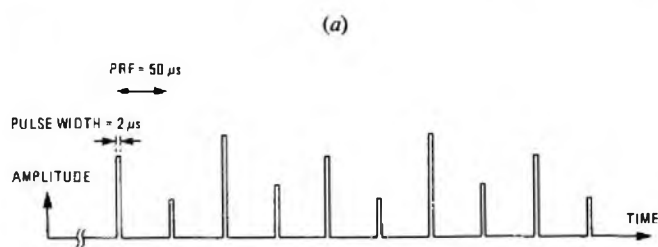
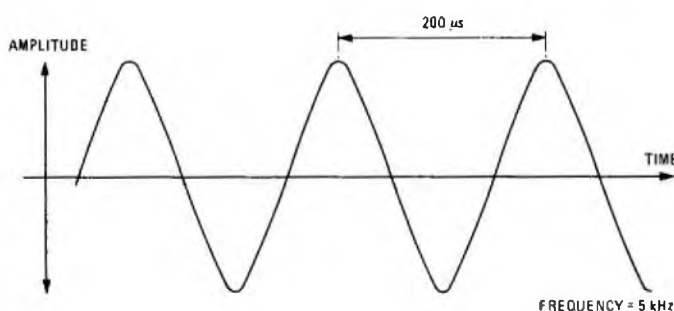
A6 (a) The Sampling Theorem states that the rate at which a waveform should be sampled to ensure that information is not lost is at least twice that of the highest frequency component of the waveform.

(b) Sketch (a) shows a 5 kHz sinusoidal waveform amplitude modulating the pulse train shown in sketch (b).

(i) When this pulse train is passed through a 4 kHz low-pass filter no signal will be observed at the output since all components of the frequency-spectrum of the modulated pulse train lie above this frequency.

(ii) When passed through a low-pass filter with a cut-off at 10 kHz a component at the modulation frequency of 5 kHz will be observed.

(iii) One component will be observed at the output of a filter with a pass-band extending from 12–18 kHz. This will be the lower sideband of the 20 kHz (50 μs period) pulse-repetition frequency modulated by the 5 kHz modulating frequency; that is, a component at 15 kHz.



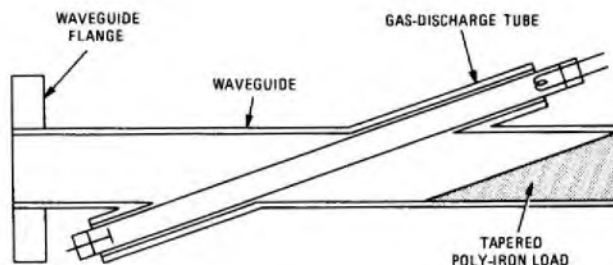
PRF: pulse-repetition frequency

(iv) A low-pass filter with a cut-off frequency of 28 kHz will pass all the above components plus the 20 kHz pulse-repetition frequency and the upper sideband at 25 kHz of the 20 kHz pulse-repetition frequency modulated by the 5 kHz signal.

Q7 (a) With the aid of a diagram, describe briefly a white-noise source suitable for measuring the noise factor of a receiver. Explain how the noise power this delivers to the receiver could be varied.

(b) A receiver has a noise factor of 9 dB and a bandwidth of 6 MHz. Calculate the minimum signal power required at the input to provide an output signal-to-noise power ratio of 26 dB. (Assume $kT = 4 \times 10^{-21} J$.)

(c) State why the value of the noise factor of a microwave receiver is usually of much greater importance than that for a similar receiver of comparable sensitivity intended for lower frequencies.



A7 (a) The gas-discharge tube noise source, shown in the sketch, is a commonly-used white-noise source for measuring the noise factor of microwave receivers. The tube, which is similar to a small fluorescent lamp, is positioned in the waveguide as shown in the sketch. When excited, the gas inside the tube becomes ionized and produces broadband noise. The electron noise temperature is constant and typically about 10 000–15 000 K. This very high excess noise temperature may be reduced by inserting attenuation between the noise source and the input to the microwave receiver under test. A 20 dB attenuator so inserted would allow the excess noise temperature of the source to be reduced to 100 K. Thus, such a source is useful for measuring receivers with widely varying noise factors; for example, from simple crystal-mixer receivers to low-noise receivers intended for satellite communications.

(b) The noise factor, F , of a receiver is defined as:

$$F = \frac{\text{input signal-to-noise power ratio}}{\text{output signal-to-noise power ratio}} = \frac{SNR_{IP}}{SNR_{OP}}, \text{ or}$$

$$F(\text{dB}) = SNR_{IP}(\text{dB}) - SNR_{OP}(\text{dB}).$$

In the example, $F = 9 \text{ dB}$ and $SNR_{OP} = 26 \text{ dB}$.

$$\therefore SNR_{IP} = 35 \text{ dB}.$$

The noise power input, P , to a receiver with bandwidth B is given by:

$$P = kTB \text{ where } kT = 4 \times 10^{-21} \text{ J, } P \text{ is in watts, } B \text{ is in hertz.}$$

$$\therefore P = 4 \times 10^{-21} \times 6 \times 10^6 = 2.4 \times 10^{-14} \text{ W.}$$

$$\text{Now, } SNR_{IP} = 10 \log_{10} \frac{\text{input signal power}}{\text{input noise power}}.$$

Therefore, the input signal power required for an input signal-to-noise power ratio of 35 dB

$$= 10^{35/10} \times 2.4 \times 10^{-14} \text{ W,}$$

$$= 7.6 \times 10^{-11} \text{ W.}$$

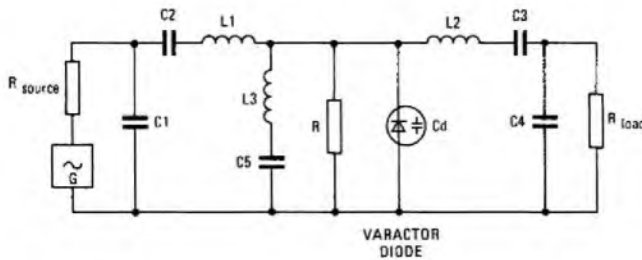
(c) Because microwave receivers normally operate over wide bandwidths, the thermal noise generated in the receiver (kTB) will be greater than that generated in a narrower-bandwidth low-frequency receiver of comparable sensitivity. Because of this, the microwave receiver must have a lower noise factor to achieve comparable sensitivity.

Q8 (a) (i) Explain in outline the principle of a semiconductor device that may be used as the active device for the local oscillator of a microwave receiver.

(ii) State TWO advantages of an oscillator using this device.

(b) Describe how a varactor diode could be used in ONE of the following applications

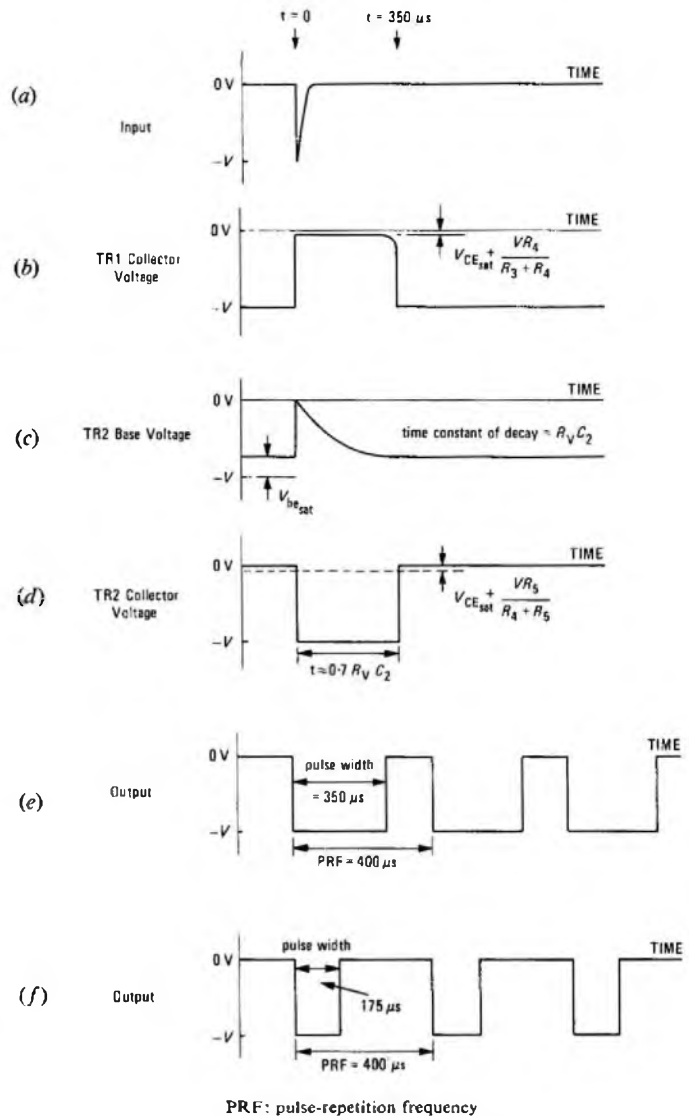
- as the tuning element of a cavity,
- as the active element of a frequency mixer, or
- as the active element of a frequency trebler.



A8 (a) See A8, Basic Microwave Communication C 1976, Supplement, Vol. 70, p. 71, Oct. 1977.

(b) (iii) The sketch shows the schematic circuit of a 166-500 MHz frequency trebler using a varactor diode as the active element.

The varactor diode is a semiconductor device that is used as a variable-reactance circuit element. The variable reactance is the junction capacitance, which varies with the applied voltage. The varactor thus has a non-linear charge/voltage relationship, and this non-linearity is used to generate harmonics of applied radio-frequency signals. In the varactor frequency-trebler shown, the input signal is applied to the diode via the series-resonant tuned circuit comprising C1, C2, the diode capacitance, Cd, and L1. To produce third and higher-order harmonics efficiently, one or more idler circuits can be added to allow currents to flow at all intermediate frequencies between the fundamental and the required harmonic. This circuit is represented by L3 and C5 in the sketch, which are series-resonant with the diode capacitance, Cd, at twice the input frequency. The trebler output is matched to the load with the series-resonant circuit C3, C4, Cd and L2. Resistance R is incorporated to improve further the multiplier action by providing a measure of automatic-bias to the diode. Using such a circuit, medium-power frequency-trebler efficiencies of up to 75% can be obtained at 500 MHz. However, for low-power applications, high multiplication factors are more readily obtained from step-recovery diodes, since these can produce high-order harmonics without the necessity for idler circuits.



To facilitate layout, questions 9 and 10 have been reproduced in reverse order.

Q10 (a) For a particular setting of RV, a single negative going trigger pulse applied to the input of the circuit shown in Fig. 2 below gives an output pulse of 350 μs duration. For this condition draw a series of waveforms showing how the following are time related to the trigger pulse:

- (i) TR1 collector voltage,
- (ii) TR2 base voltage, and
- (iii) TR2 collector voltage.

(b) The circuit is now triggered by negative pulses having a recurrence frequency of 2.5 kHz. Describe, giving reasons, the output waveform if the value of RV is

- (i) unchanged,
- (ii) doubled, and
- (iii) halved.

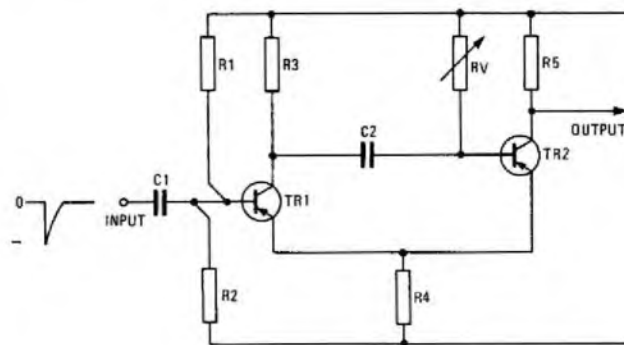


Fig. 2

A10 (a) See sketches (a)-(d).

(b) Triggering the circuit by negative pulses having a recurrence frequency of 2.5 kHz gives a period between pulses of 400 μs.

(i) Each trigger pulse gives an output pulse of 350 μs duration and for recurring trigger pulses of 400 μs period, the output waveform will be as shown in sketch (e).

(ii) Doubling the value of RV will double the time constant of $R_v C_2$ which determines the output pulse length of the monostable circuit. A single trigger pulse would therefore give an output pulse of 700 μs, but, for a recurrence period of 400 μs, the base voltage of TR2 would never reach a sufficiently negative value to switch TR2, and the output will be permanently held at the rail voltage.

(iii) Halving the value of RV will reduce the time constant to 175 μs, resulting in the output waveform shown in sketch (f).

Q9 (a) Explain why the following are essential if full advantage of wideband frequency modulation (FM) is to be exploited at the receiver:

- (i) adequate limiting, and
- (ii) de-emphasis.

(b) By means of a labelled block diagram, show where these facilities are provided in the receiver.

(c) With the aid of a diagram, explain briefly the principle of ONE of the following types of discriminator:

- (i) Foster-Seeley, or
- (ii) phase-locked loop.

A9 (a) (i) Adequate limiting of a wideband frequency-modulated signal is essential to ensure that

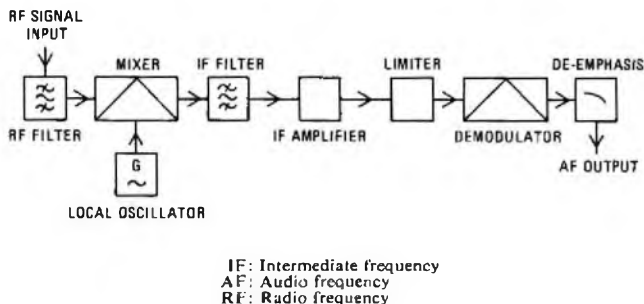
(1) signal-level variations are eliminated before the signal is applied to the discriminator, and

(2) the effect of impulsive noise and other interference is minimized by limiting the amplitude of the noise spikes.

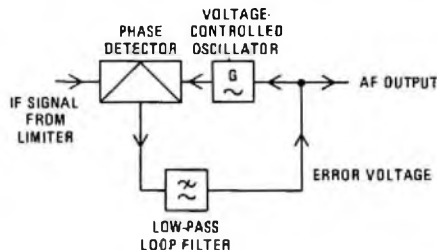
(ii) De-emphasis is essential in wideband FM receivers to restore the rising gain characteristic impressed on the signal by the pre-emphasis at the transmitter. This is done to improve the ratio of signal-to-noise in the high frequency end of the baseband and audio signal spectrum.

(b) See sketch (a).

(c) (ii) The phase-locked loop (PLL) discriminator is a feedback system comprising a phase detector and low-pass filter in the signal path and a voltage-controlled oscillator (VCO) in the feedback path. The PLL can be used as an FM discriminator because the VCO tracks the instantaneous frequency of the input signal when the PLL is locked to this signal. The filtered error voltage, which forces the VCO to remain locked with the input signal, thus becomes the demodulated FM output.



(a)



(b)

TELEGRAPHY C 1978

Students were expected to answer any 6 questions

Q1 (a) Draw typical current/time graphs, and sketch typical displays on a telegraph distortion measuring set (TDMS) for a teleprinter character affected by

- (i) bias distortion,
- (ii) characteristic distortion, and
- (iii) fortuitous distortion.

(b) What is the cumulative effect if a number of links of a telegraph circuit are affected by

- (i) bias distortion,
- (ii) characteristic distortion, and
- (iii) fortuitous distortion?

(c) Describe a test signal suitable for both start-stop and isochronous distortion measurements.

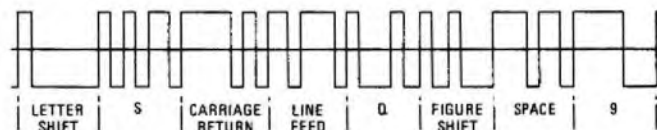
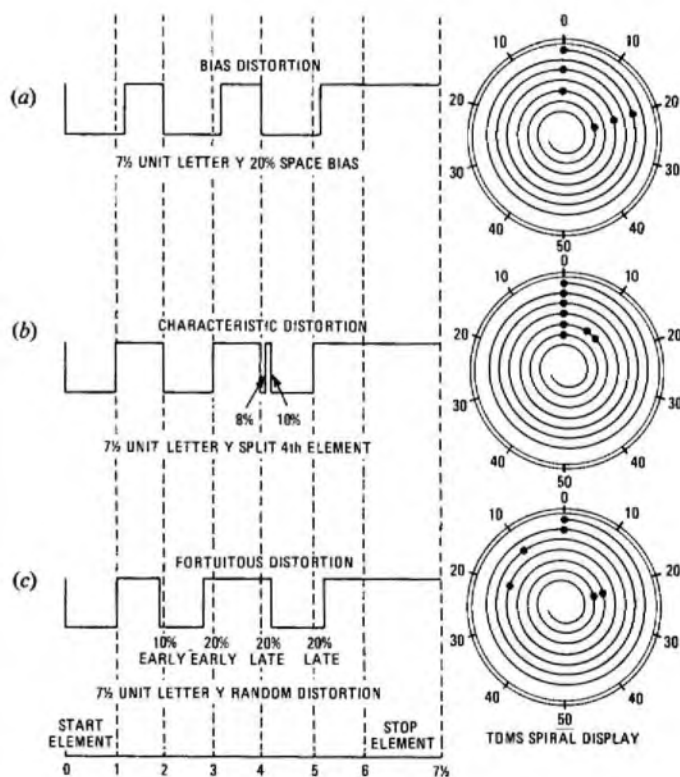
A1 (a) Sketches (a)-(c) show typical current/time graphs and distortion measuring-set displays for a teleprinter character affected by bias, characteristic and fortuitous distortion respectively.

(b) (i) Bias distortion is due to the consistent lengthening of either MARK or SPACE elements by the delay in the change from one polarity to the other. The cumulative effect of this in a number of channels in tandem will depend on the polarity and the value of the bias in each channel. The effect will be additive if all bias is of the same polarity in each link, but there will be a reduction for each channel with opposite bias. For 4 channels in tandem the probability of all channels having the same bias is about 1 in 8 although, in practice, the total value is generally about twice that of a single link. Bias distortion is the main limiting factor on a multi-link switched network.

(ii) Characteristic distortion arises from the inherent characteristics of the transmission equipment, and if several links, each of similar character, are joined in tandem, the distortion will be additive. For example, if the distortion takes the form of shortened space elements, due to slow build-up of the received signal, similar characteristics of several channels in tandem could cause the element to become progressively shorter with subsequent loss of the element. This type of distortion should also be kept to a low value in a switched network.

(iii) As fortuitous distortion is irregular and random and only a small proportion of character elements suffer maximum distortion and as any transition may be advanced or retarded, the chance of a signal suffering limiting distortion in any link is small. For several links in tandem the cumulative affect is not additive; for instance, a circuit consisting of 4 links, each with fortuitous distortion of 10%, would probably suffer overall distortion of less than 20%.

(c) The standard test message for voice-frequency telegraph channels is the Q9S signal, which consists of the characters letter shift, S, carriage return, line feed, Q, figure shift, space, 9 transmitted in that order. Each character consists of 7 elements, the stop element being



(d)

the length of one character element. The message is sent at cadence speed, and successive messages follow each other without a break. This message has been chosen because it contains a wide variety of combinations of long and short, positive and negative pulses, which ensure that the channel is adequately tested. The test message is illustrated in sketch (d).

- Q2** (a) List SIX Telex service signals and explain their meanings.
 (b) With the aid of a circuit diagram, describe how ONE of the service signals is generated and distributed in a Telex exchange.
 (c) Describe how service signals are phased and explain why this is necessary.

A2 (a) See A9, Telegraphy C 1974, Supplement, Vol. 68, p. 71, Oct. 1975.

(b) The sketch shows the method of generating and distributing printed service signals in an automatic Telex exchange. The signals are generated by a motor-driven signal-generator which is accurately speed-controlled. Spring-sets operated by cams, the peripheries of which are notched to provide the correct sequence of operation, apply the appropriate potentials to the distribution circuits. For printed service signals, the outputs from the cam spring-sets are routed through the segments of a distributor; this gives the accurate timing and correct formation necessary for the teleprinter signals.

The distributor consists of concentric rings, some of which are continuous and some divided into segments. Connexion between the segmented rings and their corresponding solid rings is made by brush arms carrying carbon brushes. To minimize wear on the distributor rings and brushes, the current flowing in each brush circuit is restricted to 4 mA. The signalling current required to operate the teleprinter which is receiving the service signal is about 20 mA, and, as a number of such teleprinters may be receiving the same service signal simultaneously, the service-signal output is applied to a number of parallel high-impedance valve circuits. Each valve controls a polarized relay, which distributes the service signal from a low-impedance source to a limited number of lines.

As shown in the sketch, the brushes, moving over the distributor rings, apply earth potential to the potentiometer network as determined by the position of the cams and their associated spring-sets. Earth potential connected to the -80 V side of the potentiometer network applies a potential of +32 V to the left-hand grid of the double-triode valve; a potential of -32 V is applied when earth potential is connected to the +80 V side of the potentiometer network. The right-hand grid

of the triode is maintained at earth potential, and, with the incoming signal at negative potential, the right-hand triode conducts and the left-hand triode is cut-off. Current flowing in the right-hand winding of the polarized relay causes the relay tongue to connect -80 V (or STOP potential) to the line. When the incoming signal is positive, current flows in the left-hand triode only, and the polarized relay connects +80 V (or START potential) to the line.

The output from the tongue of the polarized relay is from a low-impedance (10 Ω) source of ±80 V; the resistors limit the surge current under maximum output conditions. The filters are provided to suppress radio-interference signals and form a spark-quench circuit to minimize damage due to arcing across the relay contacts.

(c) The service signals are connected to each line under the control of phasing pulses. The latter are generated from the same machine as the service signals, and are accurately controlled. Phasing pulses are required so that a service signal is connected to the line at the correct instant. The demand for a service signal from any group or final selector will arrive at random, and, if the service signal were connected immediately, the distant teleprinter receive mechanism would probably start in the middle of a character and would print a mutilated signal. To prevent this, the service signal is not connected to the line until the phasing pulse indicates that a service-signal cycle is about to begin.

Q3 For an automatic error-corrected (ARQ) radio circuit

(a) draw a timing diagram to show the transmission of signals between two stations when an incorrect signal is received at the distant terminal,

(b) explain why the code for a teleprinter character is changed before transmission over the ARQ circuit, and

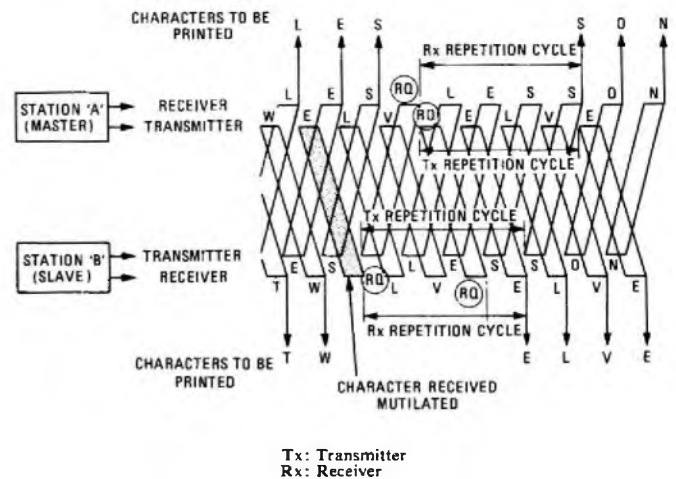
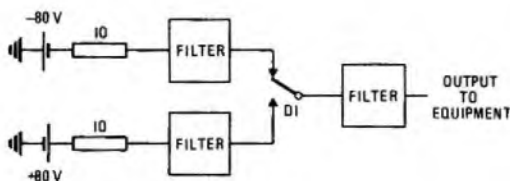
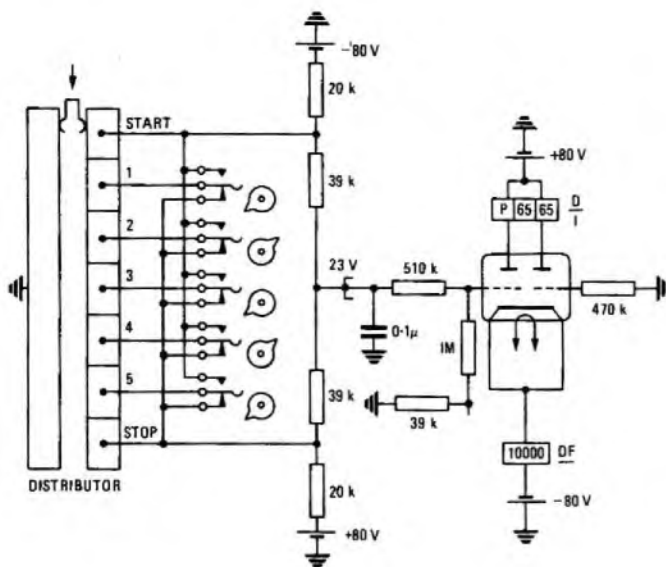
(c) describe the function of

(i) signal alpha, and

(ii) signal beta

and explain why the signals are necessary.

A3 (a) The sketch shows the timing diagram of an ARQ system responding to a detected error in one character. When this is detected at the distant terminal a request to retransmit (RQ) signal is returned to the originating station, which repeats the character in error, followed by any further characters which were transmitted during the period between the transmission of the error character and the receipt of the RQ signal at the transmitter.



(b) Teleprinter signals operating at 50 bauds as used in the Telex network are in binary code with each character comprising 5 elements. This code allows $2^5 = 32$ permutations, which, with the letter-shift and figure-shift facility, gives sufficient characters for the alphabet, the numbers 0-9 and the punctuation marks etc. necessary in the text of a message. The code has very little redundancy (that is, unused characters) and if an element of a character is not transmitted correctly, such as is often the case on a high-frequency radio circuit, an element of opposite polarity may be received at the distant terminal. This will cause the printing of a character different from the character transmitted and the message will be mutilated. If more than 5 elements are used for each character, the possibility of a change in polarity of one element producing a valid code for a different element is reduced, and an indication can be given at the distant end that an error has been received. This type of protection increases in effectiveness with the increase in the number of elements used, but a limiting factor is the effect that the more elements employed per character, the fewer words

per minute that can be transmitted. To improve the detection of errors without too great a penalty, a fixed ratio of MARK and SPACE elements for each character may be used. One such code uses four spacing elements and three marking elements for each character; the total useable combinations then is

$$P = \frac{7!}{(7-3)! \times (7-4)!} \\ = 35.$$

The 7-unit code gives $2^7 = 128$ possible combinations, and thus has a redundancy of 93 combinations. This ensures a good compromise between the number of errors which may be undetected and an unacceptable reduction in traffic-carrying capacity.

(c) Of the 35 combinations in the 8-unit error-detecting code, 32 are used for characters in the 5-unit code and the remaining 3 are used for the *alpha*, *beta* and *RQ* supervisory signals.

(i) The *alpha* signal corresponds to a continuous space signal (or START polarity) and is the Telex clearing signal. This is continuously transmitted while a channel is idle between calls.

(ii) The *beta* signal corresponds to a continuous mark, or STOP polarity and is the Telex calling signal. The *beta* signal is continuously transmitted during idle time while a call is in progress.

As the ARQ system is a synchronous time-division multiplex system, a signal must always be present on each channel to maintain the correct time relationship between both ends. Should transmission conditions deteriorate while the *alpha* or *beta* signal is present, a correction cycle would be initiated.

Q4 (a) Explain the difference between a low-pass and a band-pass filter.

(b) Draw circuit diagrams to show the components of EACH type of filter.

(c) Under what circumstances is EACH type of filter used on telegraph circuits?

(d) Sketch typical attenuation/frequency graphs for EACH filter and explain the significance of the frequency values shown.

A4 See A2, Telegraphy C 1976, Supplement, Vol. 70, p. 65, Oct. 1977 and A10, Telegraphy C 1977, Supplement, Vol. 71, p. 68, Oct. 1978.

Q5 (a) List the functions of the time-zone equipment in an automatic Telex exchange.

(b) Draw a circuit diagram and explain how and when the equipment is seized and released during a local call.

(c) How does the equipment deal with an ineffective call?

A5 (a) The time-zone equipment consists basically of a two-motion selector, a uniselector and the associated relays. The main functions of the equipment are:

(i) guarding and holding equipment used in setting up a call,

(ii) extending the *proceed-to-select* pulse to the calling subscriber,

(iii) energizing the vertical and rotary magnets of the two-motion selector, according to the first two digits dialled,

(iv) checking to determine if a barred code has been received and, if so, returning the service signal NP,

(v) checking to determine whether a call is chargeable or not,

(vi) detecting the negative potential received as a *call-connected* signal and extending WRU to the called subscriber on an inland call,

(vii) returning the occ signal to the calling subscriber if the called subscriber is engaged,

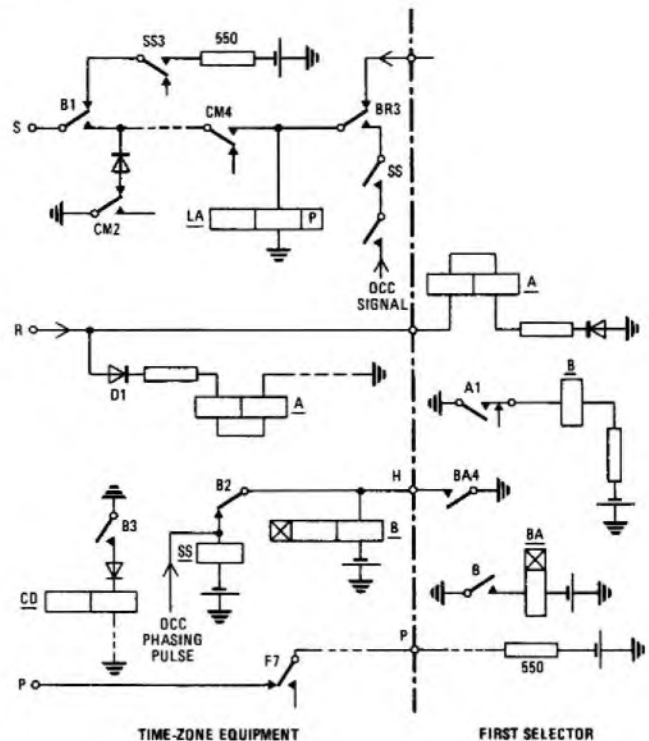
(viii) checking the meter-pulse lead for continuity and connecting meter pulses to the subscriber's meter wire at the appropriate rate, and

(ix) recognizing a *clearing* signal from the called subscriber and connecting earth potential to the calling-subscriber's circuit to clear the connexion.

(b) The sketch shows how the time-zone equipment is seized and released for a local call.

The calling condition, -80 V, is received on the R-wire to operate relay A in the first selector; relay A in the time-zone equipment does not operate because of rectifier D1. Contact A1 operates relay B, which in turn operates relay BA. Contact BA4 connects earth potential to the H-wire to operate relays SS and B in the time-zone equipment; relay SS operates before relay B as relay B is slow to operate.

Contact SS3 connects 550Ω , -80 V to the S-wire contact B1. After 50–100 ms delay, relay B operates and disconnects the -80 V potential. The 50–100 ms pulse of negative potential is transmitted to the calling subscriber and constitutes the *proceed-to-select* signal.



Contact B2 releases relay SS and contact B3 operates relay CD. The time-zone equipment is then ready to receive the selection signals from the calling-subscriber's dial.

The call may be cleared by either subscriber connecting positive potential to the S-wire; positive potential is returned on the R-wire from the distant terminal. Whichever subscriber clears, the final selector releases the chain of connexions.

Relays B and BA in the first selector release and remove earth potential from the H-wire releasing relay B in the time-zone equipment. Relay LA responds to the positive potential on the S-wire and releases relay CM (not shown). Contact CM2 connects earth potential to the S-wire to release the calling station and CM4 disconnects the through S-wire. A contact of relay B (normal) makes relay F (not shown) dependent on the uniselector in the time-zone equipment arriving at the home position. When the uniselector homes, relay F releases and at F7 restores the 550Ω testing battery from the first selector to the time-zone P-wire to indicate that the equipment is released and free to receive a further call.

(c) An ineffective call is indicated when no *answer-back* signal is received from the called subscriber in response to the WRU signal sent from the time-zone equipment. Metering does not begin unless an *answer-back* signal is detected and if no signal is detected within 1.8 s of the end of the WRU sequence, the service signal occ (*occupié* or *subscriber engaged*) is transmitted to the calling subscriber, followed by the *clear* signal which initiates the release of the call and the equipment.

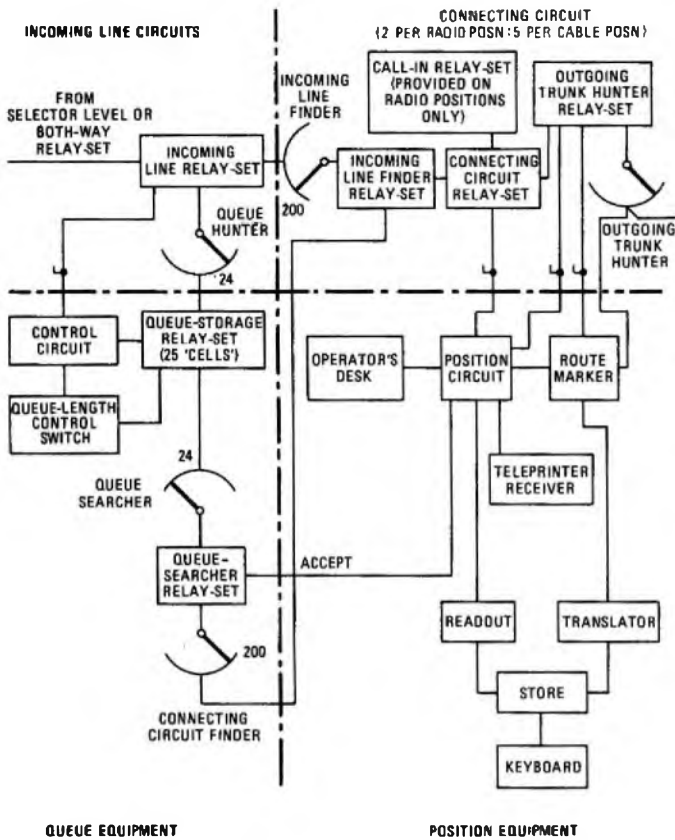
Q6 (a) With the aid of a block diagram, explain how a subscriber may gain access to the operator on a Telex international switchboard.

(b) Explain the operating procedure and the purpose of the various lamp signals when a call is processed on a radio position.

(c) What is the essential difference between the method of charging for a call on a radio position and a call on a cable position?

A6 (a) The sketch shows the queuing equipment and the position equipment of a Telex international switchboard. When the incoming line circuit is seized by a call, the incoming line relay-set causes the queue hunter to search for a free queue cell. The call is stored in the cell and the service signal MOM (*wait*) is returned to the caller. The queues are regulated by the control circuit, which ensures that calls are stored in order of arrival, and by the queue-length control switch, which is mounted on the control console and controls the length of the queue for varying traffic conditions.

When an operator is ready to accept a call, the ACCEPT key on the operator's position is operated and the queue searcher hunts for, and finds, the first engaged cell. The connecting-circuit finder searches for a free connecting circuit on the operator's position marked by the operation of the ACCEPT key. The queue searcher marks the appropriate



contact on the incoming line-finder bank via the queue hunter. The incoming line finder searches for and finds the marked incoming line relay-set and connects the incoming call to the connecting-circuit relay-set. The queue cell, queue searcher and connecting-circuit finder are then released. The ACCEPT lamp on the position glows when the operator throws the ACCEPT key and is extinguished when the ANSWER lamp associated with the selected calling circuit indicates that a call has been received. The answer-back code LONDON SWBD PXXX (the switchboard position number) is signalled to the caller, who is then in teleprinter communication with the operator and can pass the number of the wanted subscriber.

(b) The operator reads the called subscriber's number, operates the SEND CALL key and transmits the route selection digits followed by the called number. When the called station call-connected signal is received, the operator exchanges the answer-back signals of each station by operating the ANSWER-BACK key in conjunction with the SEND CALL and the SEND ANSWER keys; the two subscribers each receive the other's answer back and the call is established. The operator presses the DISCONNECT POSITION key, call timing starts and the THROUGH lamp glows. While setting up a call the ANSWER OF CALL lamp glows steadily as the operator is connected to that side; the other side flashes at 3 s intervals to show that a subscriber is held. If the operator wishes to transmit to both ends simultaneously, the SEND BOTHWAY key is operated. When the call is finished either party may clear the connexion. The THROUGH lamp is extinguished and the CLEAR lamp glows, unless traffic is held in the ARQ store. When this has been sent, the CLEAR lamp glows.

During a call on a radio circuit the RADIO lamp indicates the state of the circuit at any time. The lamp glows while traffic is held in the ARQ store, flashes at 1 s intervals if the system is cycling with traffic in store and flashes at 3 s intervals if the system is cycling with no traffic in the store.

Either subscriber may recall the operator by transmitting the characters line-feed and 4 carriage-returns. The THROUGH lamp on the circuit will flash and the operator will enter the circuit.

The supervisory lamps are listed as ANSWER, CALL, THROUGH, CLEAR and RADIO. The keys are:

- CALL SUPERVISOR/ACCEPT
- SEND ANSWER/SEND CALL
- SEND BOTHWAY/ANSWER-BACK
- THROUGH AND MONITOR/DISCONNECT

(c) The charging for a cable call is by elapsed time, but the charges for a radio call are based on the number of characters which could be

sent when the circuit is open and is not cycling. The radio calls are charged by operating the clock to a 6 s pulse for every 41 characters which could be sent.

Q7 (a) What frequencies are used for a multi-channel voice-frequency system and why are they chosen?

(b) Describe, with the aid of a sketch, a circuit suitable for generating the frequencies.

(c) How is each channel frequency modulated by an incoming DC teleprinter signal?

A7 (a) See A1, Telegraphy C 1975, Supplement, Vol. 69, p. 68, Oct. 1976.

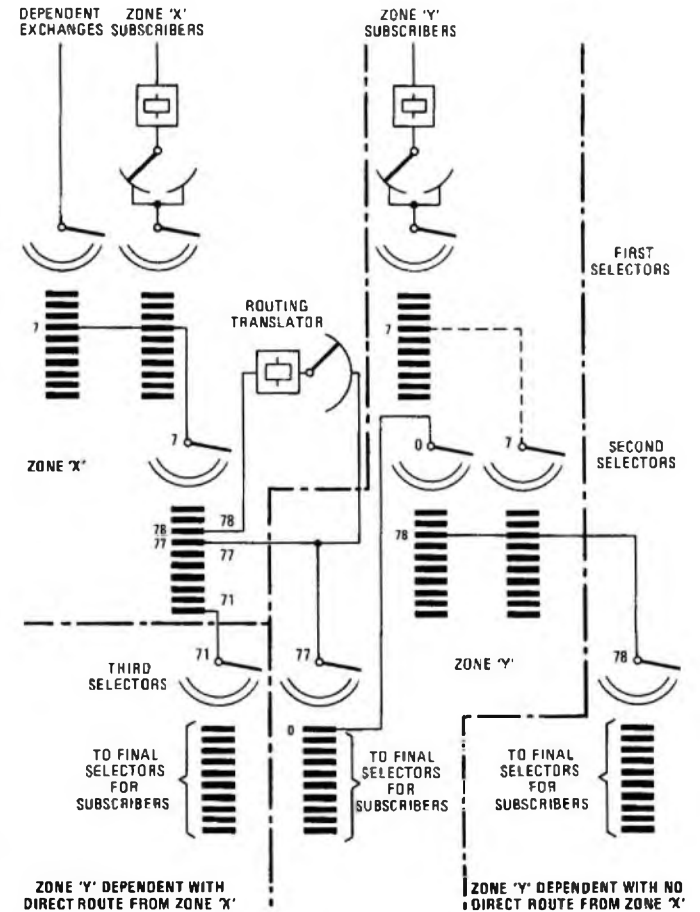
(b) See A3, Telegraphy C 1971, Supplement, Vol. 65, p. 34, July 1972.

Q8 (a) Draw a trunking diagram of an automatic Telex zone exchange with routing translators.

(b) Describe the sequence of operation of a routing translator, and explain why it is provided.

(c) With the aid of a diagram and a numbering scheme, explain how area, zone and international exchanges may be interconnected to serve a system of about 50 000 subscribers.

A8 (a) The sketch shows a trunking diagram of a zone exchange with routing translators.



(b) When it is necessary for a direct route to be provided between a zone exchange, X, and an area exchange dependent on another zone, Y, the resulting trunking arrangements give rise to a need for a routing translator, to avoid having to provide uneconomic direct routes from zone X to all other area exchanges dependent on zone Y. The trunking diagram in the sketch illustrates the use of the routing translators. The introduction of second selectors on level 7 (to cover the need for a direct route to an area exchange using the code 71) means that the

normal zone-to-zone routes between X and Y are transferred to second-selector levels appropriate to the zone-Y charging areas. The routing translator replaces the necessary digits for routing within zone Y.

The routing translator is sensitive to the level from which it is seized. A preset translation of up to four dial-pulse trains is given, any one of which can be equivalent, if required, to the group-selector level from which the routing translator is seized. The translation pulse trains are relay-generated and a mechanical pulse-generator is included as a simple digit store to permit simultaneous pulsing-in and pulsing-out. The routing translator remains in circuit for the duration of the call and is connected, as required, either to a standard group selector or to a uniselector trunk-hunter controlled by the routing translator.

The principal facilities offered by the routing translator are as follows:

(a) Guarding the incoming P-wire on seizure and release of a call until the routing translator and associated group selectors or trunk hunter are fully restored to normal.

(b) Seizing and stepping the associated uniselector to the required level. The group selector then hunts for a free trunk relay-set or causes the associated trunk hunter to hunt for a free trunk relay-set.

(c) On seizure of an associated group selector or a free trunk relay-set, transmitting the preset translation.

(d) Including in the translation, a dial-pulse train corresponding to the level from which the translator is seized; that is, any one of 10 levels depending on the particular trunking arrangement.

(e) Storing dialled digits received from the caller while the translation dial-pulse trains are being transmitted, and then repeating the stored digits.

(f) Switching through the forward and backward transmission paths when the translation and the stored digits have been transmitted.

(g) Returning the printed service signal NC (no circuit) followed by a clear signal if the trunk hunter fails to find a free trunk relay-set.

(c) See A2, Telegraphy C 1975, Supplement, Vol. 69, p. 68, Oct. 1976.

Q9 A document is to be transmitted by facsimile.

(a) Describe the THREE factors necessary to ensure transmitter and receiver synchronization.

(b) Why is synchronization important and what is the effect of variation in EACH factor on the received document?

(c) What are the standard frequencies used in facsimile transmission over

- (i) lightly-loaded cables, and
- (ii) high-frequency systems?

A9 (a) (b) In order to receive correctly a document transmitted by facsimile it is necessary that the transmitter and receiver are in synchronism. Three factors must be taken into account to establish synchronization and these are given below, with a description of the effect of variation on the received document.

Sketch (a) shows the original picture.

Sketch (b) shows the effect of constant speed error, where the speed of rotation of the receiver drum varies from the speed of the trans-

mitter drum. This gives the received picture a skewed effect. A straight line which should cross the scanning line at right angles will slope up or down depending on the speed error. Speed synchronization is ensured by having both machine speeds accurately controlled by a crystal oscillator; this gives adequate stability without the need for temperature-controlled ovens.

Sketch (c) shows the effect of incorrect phasing. It is necessary to ensure that the scanning devices occupy the same relative positions on the drum with regard to the document and the recording blank. As both document and blank are flat sheets of paper wrapped around a drum, both scanners must start at the place where the head and tail of the paper meet, and scan the length of the paper from the head, around the circumference of the drum, to the tail. Phasing pulses are sent before the picture to align the drums; phasing is achieved in about 15 s.

Sketches (d) and (e) show the effect of a difference in the index of co-operation of the two machines. The index of co-operation is the relationship between the length and breadth of the document—the ratio between height and width. The index of co-operation may be the same for two machines although their picture size may differ. In this case a perfect reproduction will result with different area but the same proportions. If D is the diameter of the drum and P is the pitch of the helix formed by a series of scanning lines, then the index of co-operation is given by

$$M = \frac{D}{P},$$

and if F is the scanning density (lines per unit length)

$$M = DF.$$

(c) (i) The CCITT-recommended frequencies for transmission over lightly-loaded cables was fixed in 1931 as follows:

- carrier frequency (f_0): 1300 Hz,
- modulation frequencies: +550 Hz and -550 Hz.

(ii) In 1951 the following frequencies were recommended for use on carrier or coaxial telephone circuits.

$$f_0: 1900 \text{ Hz,}$$

- modulation frequencies: $\pm 550 \text{ Hz.}$

The most recent (1976) CCITT recommendations for documentary facsimile transmission of an ISO A4 document over a telephone-type circuit in approximately 6 min are:

Amplitude modulation (for leased circuits only).

The facsimile signal level is higher for black and lower for white.

The carrier frequency should range between 1300–1900 Hz and will depend upon the characteristics of the circuits used.

Frequency modulation (for leased circuits and for switched connexions).

The frequency corresponding to black is normally $f_0 + 400 \text{ Hz}$ and for white, $f_0 - 400 \text{ Hz.}$

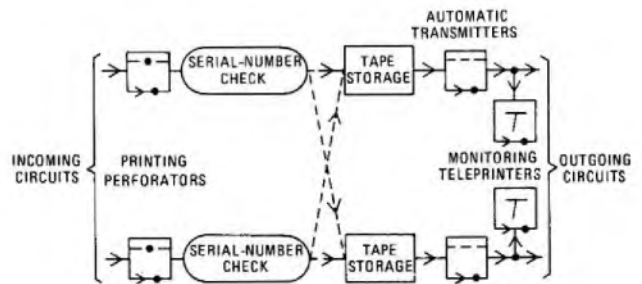
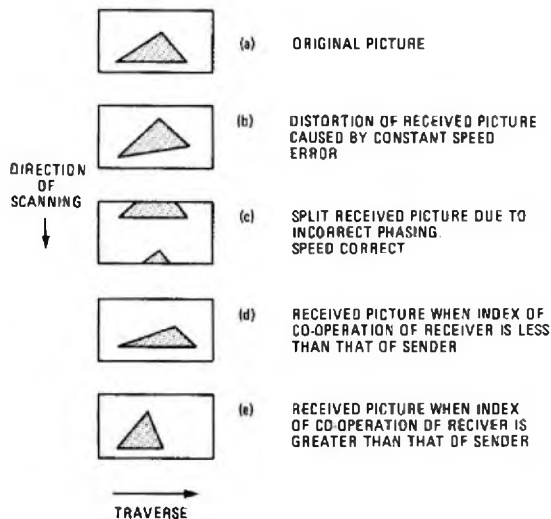
For switched connexions, $f_0 = 1700 \text{ Hz}$ (provisional). For leased circuits f_0 should range between 1300–1900 Hz: the choice of the centre frequency f_0 will depend upon the circuit characteristics. However, if the user, in some cases, wishes to use the apparatus on switched connections, $f_0 = 1700 \text{ Hz.}$

Q10 (a) Describe briefly, with the aid of block or flow diagrams, the operation of

- (i) a manual tape-relay centre,
- (ii) a semi-automatic tape-relay centre, and
- (iii) a fully automatic message-relay centre.

(b) Compare the important advantages of the THREE systems.

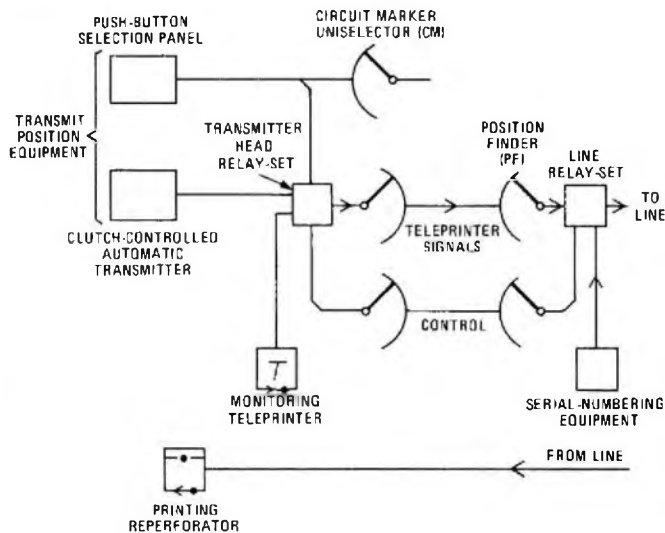
A10 (a) (i) Sketch (a) illustrates the routing of a message through a



(a)

manual message-relay centre. The incoming message is received on a printing reperforator, which perforates a tape according to the incoming signals and prints the message on the tape. The message normally bears a heading which includes the destination address and a serial number particular to the circuit. The operator checks the serial number, usually by means of a tick sheet, to verify that no message has been lost. The message is then torn from the tape and carried across the office to the automatic transmitter serving the outgoing circuit. If the required channel is in use, the tape is left in a tape-storage rack for transmission when the circuit is free. Monitoring teleprinters give a record of all messages sent, so that lost or mutilated messages can be retransmitted on request.

(ii) A block diagram of a semi-automatic push-button torn-tape relay system is shown in sketch (b).

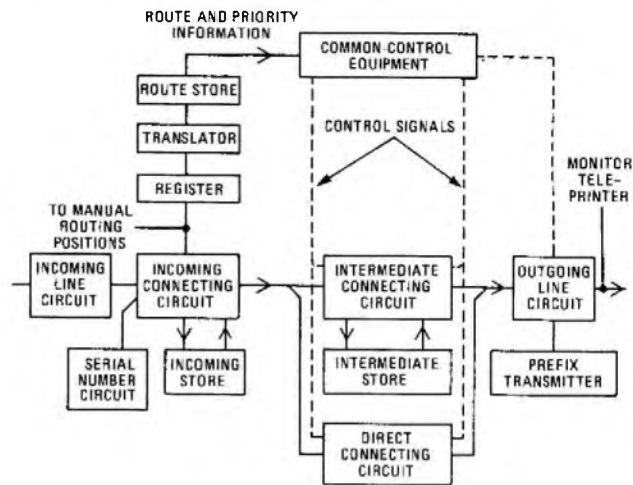


(b)

The TRANSMIT positions are located close to the RECEIVE reperforator cabinets in the operating room so that each operator can easily collect the incoming message tapes. The destination of each message is determined from the heading of the message, and the serial number is checked to indicate that no message has been lost or mutilated. The message tape is inserted into any disengaged automatic transmitter head and a push-button key, corresponding to the channel over which the message is to be sent, is pressed. A panel of push-button keys is provided for each operator to give access to all outgoing channels. The CHANNEL key is held operated until the DEMAND STORED lamp glows, indicating that the circuit-marker uniselectors (CM) has rotated to the correct position; until this lamp glows, no other transmitter head on that position should be loaded. When the required channel is available, the position-finder uniselectors (PF) searches for the calling position and connects the transmitter to the line relay-set.

The connexion established to the line relay-set causes the serial-numbering transmitter associated with that line to transmit the next message number in sequence, so that the distant terminal may check the correct functioning of the circuit. On completion of the serial number, the transmitter clutch is actuated and the message transmitted; the DEMAND STORED lamp flashes to indicate that the message is being sent. When the message has been transmitted, the tape clears the automatic transmitter and the circuit is released for further message transmissions. If the outgoing channel is engaged, the message is held in the transmitter head until the channel becomes free. To prevent a message waiting for a long period, provision is made for an alarm to be given after a predetermined time has elapsed.

(iii) Sketch (c) shows a block diagram of a fully-automatic message-relay centre. The incoming message is prepared at the distant station to conform with a fairly rigid format, in order that the relay-centre equipment may easily recognize start-of-message, serial number, priority, destination address and end-of-message codes. Each message



(c)

received is stored temporarily in the store connected to the incoming connecting circuit, so that the destination indicator may be examined and the serial number checked; the channel remains connected to the store until the end-of-message sequence is received.

The routing and priority information is decoded by the register and translator, and held in the route store until the common-control equipment is ready to process the call. A message destined for a route with one or more channels free is transmitted from the incoming store to the outgoing line-circuit via a direct connecting circuit; the outgoing line circuit and the connecting circuit are allocated by the common-control equipment. If all the outgoing circuits on the required route are engaged, an intermediate connecting circuit is used and the message is held in the intermediate store. When the outgoing circuit becomes free, the common-control equipment selects the waiting message with the highest priority and connects the store to the line. Before any message is transmitted to line, a prefix generator is connected to transmit a new start-of-message prefix and a serial number appropriate to the outgoing channel.

(b) The important advantages of the 3 systems are:

(i) *Duplex working* Each system offers economy in the use of line plant by the provision of duplex working (simultaneous transmission in both directions over a single circuit) for long-distance inter-centre circuits. Messages are queued before transmission and, in semi-automatic and automatic systems, are automatically transmitted in order. For a manual system, two message heads are loaded and the messages are transmitted in sequence; further messages are stored in the tape-storage racks above the TRANSMIT positions and are manually loaded into the transmitters as each head becomes free.

(ii) *Broadcast* For an automatic system, a broadcast message is stored and transmitted automatically as circuits become free. For semi-automatic and manual systems, a number of separate perforated tapes are prepared in a tape factory, corresponding to the number of stations which are to receive the message, and the tapes are transmitted individually as for a single message.

(iii) *Traffic capacity* The manual and semi-automatic systems use perforated tape and a surge of traffic may be accommodated by an increasing quantity of received tape awaiting transmission when conditions ease. A fully automatic system has limited storage and diverts heavy traffic to overflow positions for manual attention.

(iv) *Economy of staff* A fully automatic system uses no operators, but may have an increased maintenance requirement due to the complexity of the equipment. A semi-automatic system employs fewer operators than a manual system which is the most expensive in staff.

(v) *Priority, Security, Flexibility* The limitations of any automatic equipment are most apparent when dealing with emergencies, priorities and security. The manual system offers the greatest flexibility in non-routine matters, although for the majority of systems (for example, telegram traffic), a rigid format and operating procedure at the originating station cater for almost all requirements.