SUPPLEMENT

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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.

For economic reasons, alternate issues of the Supplement are now published in 32-page and 16-page sizes.

TELEGRAPHY B, 1974

Students were expected to answer any 6 questions

Q. 1. *For the transmission of telegraph signals, what are the advantages and disadvantages of*
(*a*) *single-current signalling,*
(*b*) *double-current signalling, and*
(*c*) *a.c. transmission?*
Draw a simple diagram to show the operation of each system.

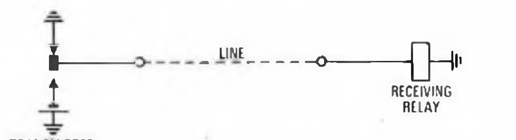
A. 1. (*a*) Sketch (*a*) shows a d.c. signalling arrangement using a single battery at the outstation with an earth return. As a variation, the battery may be located at the receiving instrument, with the outstation signalling by means of earth-potential and disconnexion conditions. Another system, largely used in the USA, has the outstation's transmitter and receiver in series with the circuit, connected as a loop.

The advantages of single-current working are that only one battery is required, and this can be located at a central office. Also, where loop signalling is used, interference with other circuits in the same cable is avoided. The main disadvantage is that the line capacitance, which may reach high values on long lines, causes successive signals to merge, unless a slow speed of working is adopted. A further disadvantage is that the receiving relay is mechanically biased, so that it restores during periods of no current. This requires the relay to be frequently adjusted to give equal periods for current and no-current signals under varying line conditions. The residual magnetism in the core of the relay, due to the unidirectional flow of current, can also cause distortion of the signals.

(*b*) Sketch (*b*) shows a double-current signalling arrangement with an earth return. This system requires 2 batteries at the outstation and, with single-wire earth-return signalling, a filter has to be employed at the transmitter to prevent interference with telephone circuits in the same cable. Double-current signalling reduces the effect of line capacitance on the speed of signalling, by reversing the flow of current with each signal of opposite polarity. It also increases the rate of discharge and recharge of the line capacitance, so that signals may be sent more rapidly without causing distortion. This method of signalling eliminates the difficulties associated with biased relays, as the receiving relay may be adjusted to be neutral, making the relay more sensitive, and permitting faster transmission with a smaller working current.

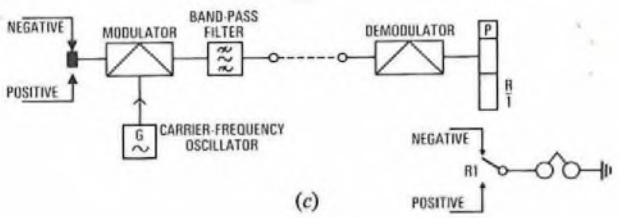
(*c*) Both of the above methods of d.c. signalling have the disadvantage that, unless very heavy conductors are used, the current is so attenuated for distances of over about 40 km that repeating relays have to be installed. To overcome this, a.c. transmission may be used, as illustrated in sketch (*c*).

The telegraph signal is used to modulate a voice-frequency carrier signal which, being in the audio range, can be transmitted over telephone circuits, using the same line amplifiers. The range of the telegraph circuit is, thus, the same as that of a telephone circuit. One telegraph circuit, operating at 50 bauds, does not effectively use the bandwidth of one telephone circuit, and multi-channel voice-frequency systems are used, whereby up to 24 telegraph circuits are simultaneously transmitted over one telephone circuit. The disadvantages of a.c. signalling are that the equipment is costly, complicated and requires more space than that for d.c. signalling.



(*a*)

(*b*)



(*c*)

Q. 2. *A teleprinter operates at 50 bauds with a character length of $7\frac{1}{2}$ units.*
(*a*) *Calculate*
(*i*) *the time taken to transmit one character, and*
(*ii*) *the speed of transmission in words/min.*
(*b*) *What is the maximum number of different characters which may be transmitted by this teleprinter, and how is this affected by the use of the letter-shift/figure-shift facility?*
(*c*) *Indicate the range of the printed characters offered by a teleprinter and list the non-printed characters.*

A. 2. (*a*) (*i*) For a teleprinter operating at 50 bauds, the shortest signal element

$$= \frac{1}{50}\,\text{s} = 20\text{ ms.}$$

Hence, the time taken to transmit one character

$$= 7{\cdot}5 \times 20 \times 10^{-3}\,\text{s} = \underline{150\text{ ms.}}$$

(*ii*) An average word is considered to consist of 5 characters and a space; i.e., 6 characters. Hence, the time taken to transmit one word

$$= 6 \times 150 \times 10^{-3}\,\text{s} = 900\text{ ms.}$$

Thus, the speed of transmission

$$= \frac{60}{900 \times 10^{-3}} = \underline{66{\cdot}67\text{ words/min.}}$$

(*b*) Each character consists of 5 signalling elements, one *start* element, and one *stop* element equal to $1\frac{1}{2}$ *start* or signalling elements. Therefore, the number of possible character combinations which may be transmitted

$$= 2^5 = 32.$$

This number of characters is insufficient to meet practical requirements since the letters of the alphabet use 26 characters, leaving only 6 characters for numerals, etc. This is overcome by reserving 2 of the characters for shift functions. In this way, the receiving type-head may be moved to print characters selected from one of 2 rows, in a similar manner to the upper-case and lower-case functions of a typewriter. In theory, 60 separate characters may be printed, but some of these, for example, *word space*, *line feed* and *carriage return*, are common to both functions. Also, one character, signal No. 32, which has 5 elements of the *start* polarity, is not used, since a line fault can cause the generation of a continuous *start* polarity, resulting in the continuous printing of that character.

(*c*) The printed characters offered by a teleprinter are

(*i*) the 26 letters of the alphabet,
(*ii*) 10 numbers, 0–9,
(*iii*) punctuation marks (for example, colon, comma, full stop, brackets, question mark, "equals" sign, "plus" sign, hyphen and solidus) and
(*iv*) certain secondary characters, such as £ and @, which are optional.

The non-printed characters are *carriage return*, *line feed*, *letter shift*, *figure shift*, *word space*, signal No. 32, and the secondary functions of D (*who are you?*) and J (*bell*).

Q. 3. (*a*) *How do the following affect the speed of signalling of a d.c. teleprinter circuit?*

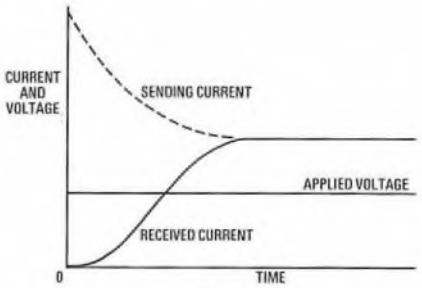
(*i*) *Line capacitance.*
(*ii*) *Teleprinter-receiver inductance.*

(*b*) *With the aid of a diagram and graphs, explain how a signal-shaping network may be used to improve the speed of signalling.*

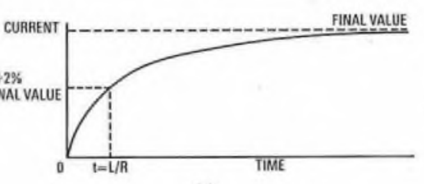
A. 3. (*a*) (*i*) For a line which contains series resistance and parallel capacitance, the time for the current at the distant termination to reach its maximum value is directly proportional to the product of the capacitance and the resistance of the circuit. A line may be considered to consist of a series of sections, each made up of a resistance shunted by a capacitance. When a voltage is applied at one end of the circuit, the capacitance in each section is charged in turn. The current at the transmitter is initially high as the current charges the capacitance, whilst the current at the receiver is very small and rises gradually as the line capacitance is charged. The current in the receiver rises to 63·2% of its final value in a time $t = CR$ seconds, where C is the total capacitance of the line (F), and R is the resistance (Ω).

The line capacitance thus delays the flow of current through the receiver and, if the current does not reach a value sufficient to operate the receiver before the next signal is received, successive signals can merge and the message become garbled. To prevent this, the speed of signalling must be reduced, to allow the receiver current to reach the operating value before the next signal is received.

Sketch (*a*) shows a typical graph of sending current, received current and applied voltage, plotted against time, for a long telegraph line.



(*a*)



(*b*)

(*ii*) The inductance of a teleprinter receiver has a similar effect to that of the line capacitance, in slowing the rise in the received current. The change of current in an inductor is opposed by a back e.m.f. The current increases in proportion to the ratio L/R, where L is the inductance (H). The current in the receiver rises to 63·2% of its final value in a time $t = L/R$ seconds. Sketch (*b*) shows a typical graph of the rise of current in an inductance for a suddenly-applied voltage.

(*b*) See A.1, Telegraphy B, 1973, *Supplement*, Vol. 67, p. 47, July 1974.

Q. 4. (*a*) *Distinguish between the use of a teleprinter broadcast network and a teleprinter conference network.*

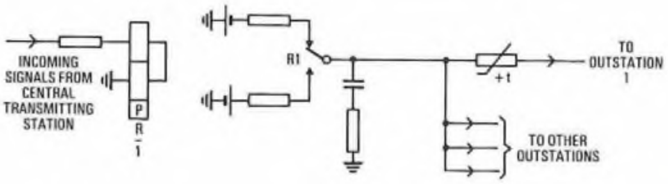
(*b*) *Draw circuit diagrams to explain the operation of* (*i*) *a broadcast unit and* (*ii*) *a conference unit.*

(*c*) *Explain how the connexions of a teleprinter station, connected to a conference unit, are arranged to provide a local record.*

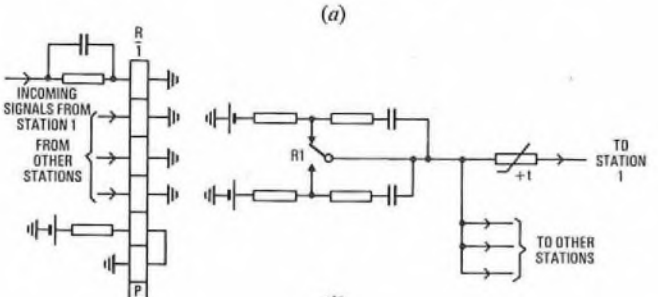
A. 4. (*a*) Transmission on a broadcast network normally takes place from one central point, with each of a number of outstations receiving the message. No message may be sent from any outstation for transmission over the network, although the return path is occasionally used for an acknowledgement signal.

For a conference network, a number of outstations are connected to a central point, such that any station may transmit a message to be received by all the other stations. If more than one station transmits at a time, the simultaneous messages interact to cause garbled signals on the network. The mutilated messages are detected on the local copy at the transmitting stations, and transmission ceases. The messages are then retransmitted in turn, depending on the priority allocated to each station. To prevent mutilation, arrangements are normally made for stations to operate according to a time schedule.

(*b*) (*i*) Sketch (*a*) shows the circuit diagram of a broadcast unit. Incoming signals from the central transmitting station are repeated to the outstations by relay R.



(*a*)



(*b*)

(*ii*) Sketch (*b*) shows the circuit diagram of a conference unit. Incoming signals from any station are repeated to all stations by relay R.

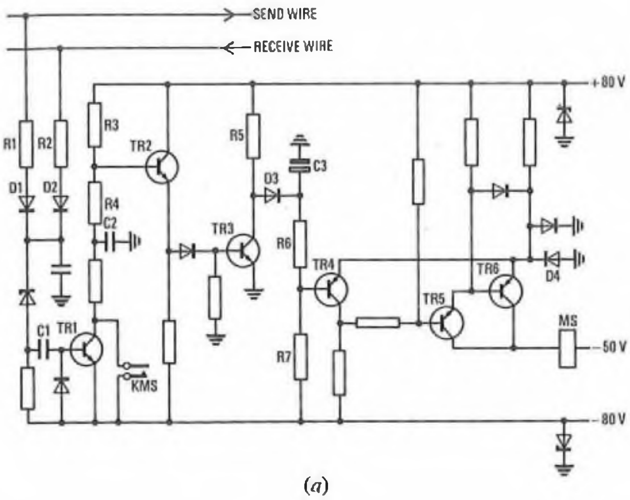
(*c*) A standard teleprinter station is normally connected to give a local record via the SEND/RECEIVE switch on the teleprinter. In this way, the transmitted signals are connected immediately to the receiver. However, when the teleprinter is connected to a conference unit, a local record is also received from the conference unit. Due to the difference in the times of propagation, the local copy would be mutilated if the 2 signals were received together. To prevent this, the local record obtained via the SEND/RECEIVE switch is disconnected. A LOCAL key is sometimes provided to reconnect the SEND/RECEIVE-switch circuit, to allow local testing.

Q. 5. (*a*) *With the aid of a diagram, describe the operation of the* MOTOR *switch of a teleprinter connected to*

(*i*) *a point-to-point private circuit, and*
(*ii*) *a switched network, such as Telex.*

(*b*) *List the desirable features of a motor required to drive a teleprinter.*

A. 5. (*a*) (*i*) Sketch (*a*) shows a diagram of the motor-control circuit used with a teleprinter serving a private circuit. When the line is not in use, there is a negative potential on both the SEND and RECEIVE wires. Diodes D1 and D2 are reverse-biased, transistor TR1 is not conducting, and transistors TR2 and TR3 are conducting. The base of transistor TR4 is at negative potential and, hence, transistor TR4 is conducting and transistors TR5 and TR6 are not conducting. Therefore, no current flows through the motor-starting relay, MS.



(*a*)

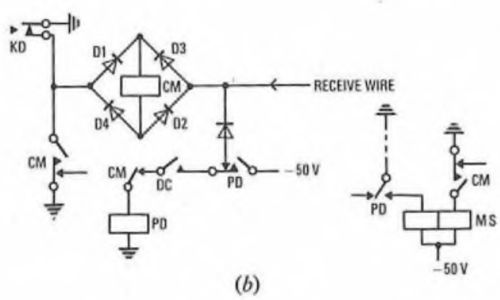
When a *start* signal is received from the distant terminal, positive potential is applied to resistor R2, forward-biasing diode D2, and a pulse of positive potential is applied to the base of transistor TR1 through capacitor C1. Transistor TR1 conducts and, as capacitor C2 charges to negative potential, the base of transistor TR2 becomes more negative, until transistor TR2 ceases to conduct. When the emitter of transistor TR2 is at about zero potential, transistor TR3 ceases to conduct, and capacitor C3 charges to +12 V via resistor R5 and diode D3. As capacitor C3 charges, the base of transistor TR4 becomes positive and transistor TR4 ceases to conduct. The base of transistor TR5 becomes negative, and transistors TR5 and TR6 rapidly become saturated. Hence, a current flows through relay MS from the −50 V supply to earth potential via diode D4. Contacts of relay MS connect the mains supply to the motor.

As signals continue, capacitor C2 remains charged, and the motor continues to run.

When signals cease, a steady negative potential remains on the line, and capacitor C2 discharges slowly via resistors R3 and R4. After about 5 s, the emitter of transistor TR2 rises to zero potential and transistor TR3 conducts. The collector potential of transistor TR3 falls to near zero potential, and diode D3 is reverse-biased. Capacitor C3, which is charged to +12 V, starts to discharge to −12 V through resistor R6 and R7. After about 90 s, capacitor C3 reaches approximately zero potential, and diode D3 becomes forward-biased, to prevent further discharge. The base of transistor TR4 is held at negative potential by the potential divider formed by resistors R6 and R7, and transistor TR4 conducts. Hence, transistors TR5 and TR6 cease to conduct, relay MS releases, and the motor stops.

If the motor is to be started locally, in order to send a message or prepare copy, key KMS is operated, simulating transistor TR1 in its conducting state, and relay MS operates. Pulses of positive potential on the SEND wire retain the charge on capacitor C2 through resistor R1 and diode D1, and relay MS remains operated as before, until a negative potential has persisted on both the SEND and RECEIVE wires for about 90 s.

(*ii*) Sketch (*b*) shows the circuit diagram of a motor-starting relay for a Telex terminal. The disengaged condition on the RECEIVE



(*b*)

wire is a disconnexion or earth potential and, hence, relay CM is normal. When an incoming call is received, a negative potential is connected to the RECEIVE wire, and relay CM operates through diodes D1 and D2. A contact of relay CM operates the motor-starting relay, MS, which connects an a.c. mains supply to the motor. Negative teleprinter signals on the RECEIVE wire hold relay CM through diodes D1 and D2, and positive signals hold relay CM through diodes D3 and D4. Relay CM is released when the call is cleared by a disconnexion or earth potential on the RECEIVE wire, thus releasing relay MS and stopping the motor.

When an outgoing call is originated, the DIAL key, KD, is operated, operating relay DC (not shown) and connecting a negative potential to the SEND wire to the exchange. When the *proceed-to-dial* pulse of negative potential is received on the RECEIVE wire, relay PD operates and a contact of that relay operates relay MS. When the call is connected, relay CM operates to negative potential and holds to negative and positive pulses, as for an incoming call.

(*b*) The desirable features of a teleprinter motor are that it should have

(*i*) a constant speed, to ensure minimum distortion,
(*ii*) a high starting torque with high acceleration,
(*iii*) negligible maintenance costs, for example, by having no brushes,
(*iv*) reliability,
(*v*) a low power consumption and heat generation, with an overload tolerance, and
(*vi*) low noise and cause negligible electrical interference.

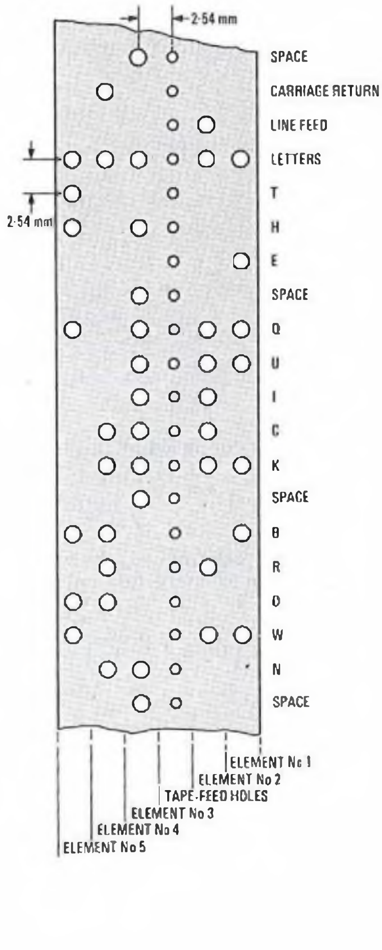
Q. 6. (*a*) *What are the main features of an automatic transmitter?*

(*b*) *Sketch and describe the operation of the transmitting mechanism, and explain what arrangements are made to ensure minimum distortion of the transmitted signal.*

(*c*) *Draw a labelled sketch of a typical section of 5-unit tape used with the transmitter.*

A. 6. (*a*) The main features of an automatic transmitter are

(*i*) a governed motor, to give an accurate, constant speed,
(*ii*) a striker-type transmitter, to reduce distortion,
(*iii*) transmission at cadence speed, with the automatic insertion of *start* and *stop* elements for each character,
(*iv*) clutch drive, to give controlled starting and stopping of the tape or pulsed release of each character,



(*v*) control of the perforated tape by a tape-guide and tape-feed wheel,
(*vi*) peckers, to sense the tape perforations,
(*vii*) tight-tape and tape-out sensing mechanisms, and
(*viii*) the transmission of each character complete; that is, no mutilation of the first character or interruption of any succeeding character until the *stop* element has been transmitted.

(*b*) See A.6, Telegraphy B, 1970, *Supplement*, Vol. 64, p. 26, July 1971.

To ensure minimum distortion of the transmitted signal, it is essential that the transit time of the transmitting contact is small, the contact pressure is adequate, no bounce or chatter occurs, and that the tongue transmits positive and negative signals of equal duration. These criteria are satisfied by the use of the striker-type transmitter and the jockey-roller mechanism.

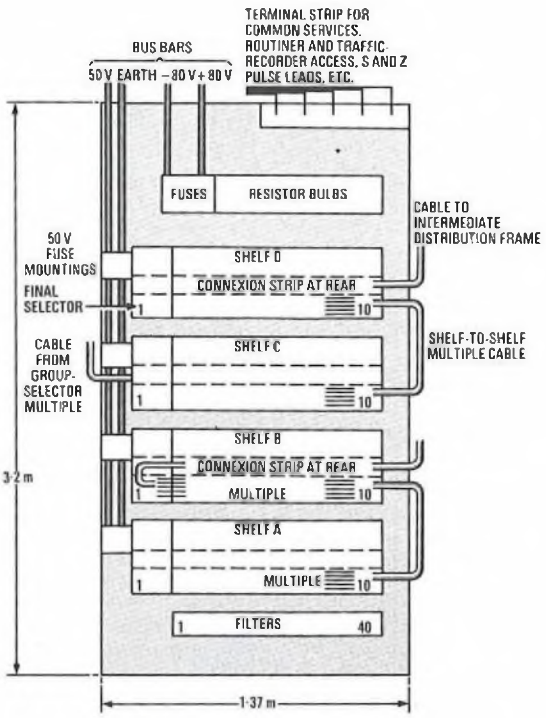
(*c*) The sketch shows a typical section of 5-unit tape used with the transmitter.

Q. 7. (*a*) *Sketch the arrangement of apparatus and cable on a rack suitable for housing final selectors in a Telex exchange.*

(*b*) *For the purpose of determining floor loading, estimate the effective area occupied by this type of rack.*

(*c*) *What considerations govern the amount of power required by a fully-equipped rack?*

A. 7. (*a*) The sketch shows the general arrangements of a typical final-selector rack at a Telex exchange.



(*b*) The effective floor area occupied by this type of rack

$$= l \times \left(w + \frac{g_w + g_a}{2}\right) \text{ metres,}$$

where l is the length of the rack (m), w is the width of the rack (m), g_w is the width of the wiring gangway (m), and g_a is the width of the apparatus gangway (m),

$$= 1\cdot37 \times \left(0\cdot36 + \frac{0\cdot48 + 0\cdot74}{2}\right),$$

$$= \underline{1\cdot33 \text{ m}^2}.$$

(*c*) The amount of power required by a fully-equipped rack may be determined by multiplying the ampere-hour consumption per item during the busy hour by the number of items which the rack can hold. Different amounts of power are required from the −50 V and ±80 V supplies. For instance, a 200-outlet final selector has the following consumption rates during the busy hour.

Supply (V)	Consumption (A h)
−50	0·16
+80	0·006
−80	0·005

Q. 8. (*a*) *Explain the methods of sending a telegram by*
(*i*) *Phonogram,*
(*ii*) *Printergram, and*
(*iii*) *telephone-telegram.*

(*b*) *What arrangements are made in a large public telegraph office to ensure that the flow of telegrams through the office is smooth and efficient?*

A. 8. (*a*) See A.7, Telegraphy B, 1970, *Supplement*, Vol. 64, p. 27, July 1971.

(*b*) Within large public telegraph offices, it is necessary to employ some system of circulation and distribution to ensure that telegrams are retransmitted, or passed to the delivery point, as quickly as possible. Conveyor belts and penumatic tubes are used for economical and rapid distribution, with a central circulation table as the focal point of the system. Incoming messages from Phonogram positions, teleprinter positions or pneumatic tubes are sorted at the circulation table and forwarded by conveyor belt to teleprinter positions for onward transmission, or to segregation and addressing tables for local distribution. From the addressing tables, messages are passed to the delivery room by pneumatic tube.

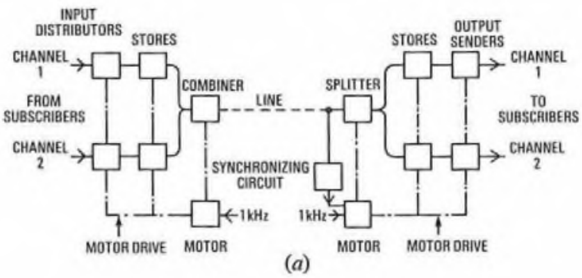
The grouping of teleprinter positions, the provision of patching-jack fields and spare positions, and the use of perforated tape and automatic machines, also assist in ensuring that the delay in forwarding a telegram is as small as possible.

Q. 9. (*a*) *With the aid of a block diagram, explain the operation of a 2-channel time-division-multiplex telegraph system.*

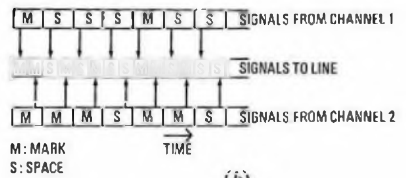
(*b*) *What are the advantages and disadvantages of using this type of system for circuits on the Telex network?*

(*c*) *What is the aggregate baud speed of such a system when transmitting 411 characters/min on each channel, using a 7-unit code?*

A. 9. (*a*) Sketch (*a*) shows a block diagram of a 2-channel time-division-multiplex telegraph system. This system allows each channel



(*a*)



(*b*)

exclusive use of the transmission path for a short, fixed period of time. The equipment may send one element at a time, or one character at a time, depending on the type of system in use. Sketch (*b*) illustrates the signals in the 2 channels and the transmission path for an interleaved-element system. The sending and receiving terminations of the circuit must operate in synchronism, so that the elements or characters from either input channel are directed to the appropriate output channel. Signals from each channel are received on an input distributor and stored. The combiner transmits each element or character to line in cyclic order. The splitter at the distant station operates in synchronism with the combiner, and separates characters or elements for each output circuit. As the system is synchronous, the *start* and *stop* elements of each character are not required to be transmitted over the system, but are re-inserted at the receiving equipment before the characters are forwarded to the receiving-subscribers' teleprinters.

(*b*) The advantages of using such a system are that 2 circuits may be accommodated on one transmission path if the bandwidth is sufficient and, with the omission of the *start* and *stop* elements, more signalling elements can be sent for a given bandwidth than for 2 separate start-stop circuits. With synchronous working, greater protection is given against distortion on circuits such as radio channels, which are subject to fading and interference. Additional elements may also be added to the synchronous signals to give parity-check or error-correction facilities.

The disadvantages of this type of system are that it is costly and complicated, thus requiring additional maintenance. The necessity to synchronize the sending and receiving equipment prevents flexibility and makes the operation of tandem circuits difficult.

(*c*) For 2 channels operating at 411 characters/min, each channel using a 7-unit code, the transmission rate

$$= \frac{2 \times 7 \times 411}{60} = 95 \cdot 9 \text{ elements/s.}$$

Therefore, the system operates at 95·9 bauds.

Q. 10. (*a*) *Draw a circuit diagram to show the arrangements at an engineering control board (ECB) for connecting a subscriber's circuit to the test desk.*

(*b*) *What other facilities are offered on the ECB for the control of subscribers' lines?*

(*c*) *Describe briefly how access may be gained to a subscriber's line from the test desk using a test final-selector, and explain how this differs from access gained through the ECB.*

A. 10. See A.3, Telegraphy B, 1969, *Supplement*, Vol. 63, p. 38, July 1970; and A.8, Telegraphy B, 1971, *Supplement*, Vol. 65, p. 6, Apr. 1972.

TELEPHONY B, 1974

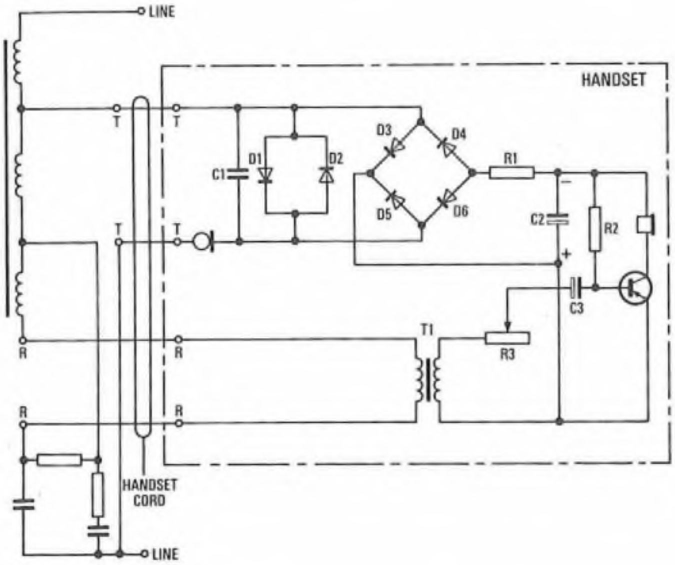
Students were expected to answer any 6 questions

Q. 1. (*a*) *Sketch the circuit of a telephone instrument fitted with an amplifier to boost the reception of speech.*

(*b*) *Explain how line current is used to power the amplifier.*

(*c*) *What considerations limit the maximum gain that such an amplifier should provide?*

A. 1. (*a*) The sketch shows the transmission circuit of a telephone instrument fitted with an amplifier to boost received speech signals. The small transistorized amplifier is mounted in the hollow handle of a 4-wire handset.



(*b*) The amplifier requires a 3 V d.c. supply. When the instrument is connected to a subscriber's line, the line current feeding the transmitter develops a direct voltage of 3 V across the forward resistance of diode D1. The non-linear characteristic of diode D1 tends to maintain this value of voltage for different values of line resistance. To cater for reversals in the line polarity, a similar element, diode D2, is connected in parallel with diode D1, but in the opposite sense. The effect of the resistance of diodes D1 and D2 on speech currents generated by the transmitter is minimized by capacitor C1, which provides a low-impedance shunt path for the alternating speech signals.

The polarity of the 3 V supply feeding the amplifier must not change, and the bridge rectifier formed by diodes D3–D6 ensures that the polarity is always correct.

Incoming speech signals, appearing across terminals RR, are applied to the base of the transistor via matching transformer T1, gain control R3, and coupling capacitor C3, and the amplified output current drives the receiver. Resistor R1 and capacitor C2 decouple the amplifier's output and the power supply, to minimize the feedback of high-level signals from the output into the transmitter circuit. Resistor R2 provides the necessary base bias for the transistor amplifier.

(*c*) This type of instrument is intended for partially-deaf subscribers, and the amplifier has a maximum gain of about 25 dB. The gain is so limited because of the instrument's tendency to "howl" at higher values of gain. Howling occurs because sufficiently-loud sounds emitted by the receiver are acoustically fed back to the transmitter via the intervening air-path or vibrations in the handset case. The transmitter retransmits these signals, via the sidetone path, back to the receiver, where they are further amplified, so building-up the oscillatory howl. Howling is most likely to occur where the line has an impedance which differs considerably from the value of the balance impedance associated with the anti-sidetone induction coil.

Q. 2. *Consider an STD call from a coin-box telephone connected to a satellite non-director exchange.*

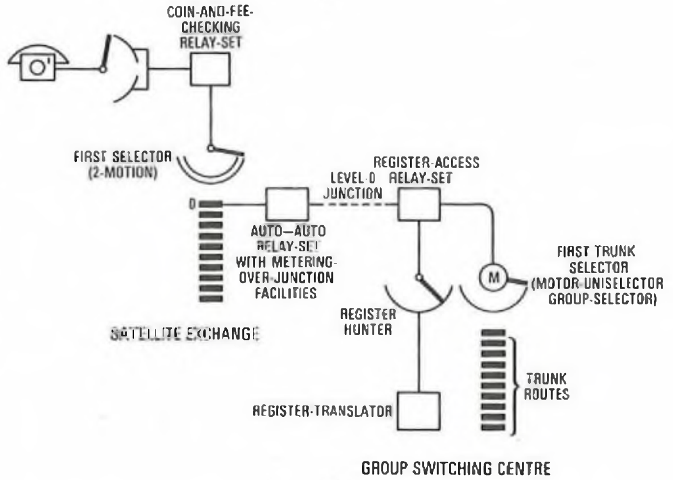
(*a*) *Draw a trunking diagram of the connexion as far as the first trunk-switching-stage at the group switching centre and identify the point at which the charge rate for the call is determined.*

(*b*) *Give an outline of the method used to signal to the coin-and-fee-checking relay-set*

(*i*) *the value of coins inserted by the caller, and*

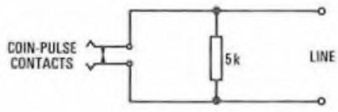
(*ii*) *the charge levied for the call.*

A. 2. (*a*) Sketch (*a*) shows the trunking diagram for an STD call from a coin-box telephone connected to a non-director satellite exchange as far as the first trunk selector at the group switching centre (GSC). The digits dialled by the calling subscriber are, typically, of the form 0*XXX YYYYYY*, where 0 is the STD-access digit, *XXX* identifies the called exchange, and *YYYYYY* identifies the wanted subscriber within that exchange. The register-translator at the GSC receives and stores all the digits following the STD-access digit and, after *XXX* has been stored, is able to identify both the charge rate appropriate to the call and the routing digits (translation) necessary to route the call through the inland trunk network. The charge rate is, therefore, determined by the register-translator, and is signalled back to the register-access relay-set, which remains held throughout the call and applies the necessary metering pulses.



(*a*)

(*b*) (*i*) The pressure used to insert a coin is made to lift a bank of cams in the coin-collecting box. When the coin is fully inserted, the cam bank falls under gravity at a governed speed, operating various contact units to produce coin pulses. A 2p coin raises the cam bank sufficiently to transmit a single coin pulse as it returns to normal; a 10p coin raises it higher, to transmit 5 coin pulses. Coin pulses are signalled by the coin-pulse contacts which, when open, insert a 5 kΩ resistance into the line loop, as illustrated in sketch (*b*). The coin-and-fee-checking relay-set detects and registers the 5 kΩ loop coin pulses, recording them as an accumulated credit to the calling subscriber.



(*b*)

(*ii*) As the call progresses, metering pulses are returned by the register-access relay-set to the auto-auto relay-set with metering-over-junction facilities at the satellite exchange. The pulses are transmitted over the junction in the form of slow reversals, which are not heard by the subscribers, at intervals depending on the charge-rate information stored in the register-access relay-set and the tariff applicable to the time of day when the call is made. The auto–auto relay-set with metering-over-junction facilities converts the pulses to positive-battery pulses, applying them to the P-wire back to the coin-and-fee-checking relay-set via the first selector. At the coin-and-fee-checking relay-set, the accumulated debit, represented by the metering pulses, is compared with the accumulated credit information received from the coin-collecting box. When the debit exceeds the credit, the coin-and-fee-checking relay-set applies pay tone to the line.

Q. 3. (*a*) *Devise a suitable linked-numbering scheme for a main exchange with 5 satellite exchanges which, together, cater for an ultimate capacity of 30 000 lines.*

(*b*) *With the aid of a trunking diagram, explain the routing of calls from one of the satellites to exchanges inside and outside the linked-numbering scheme.*

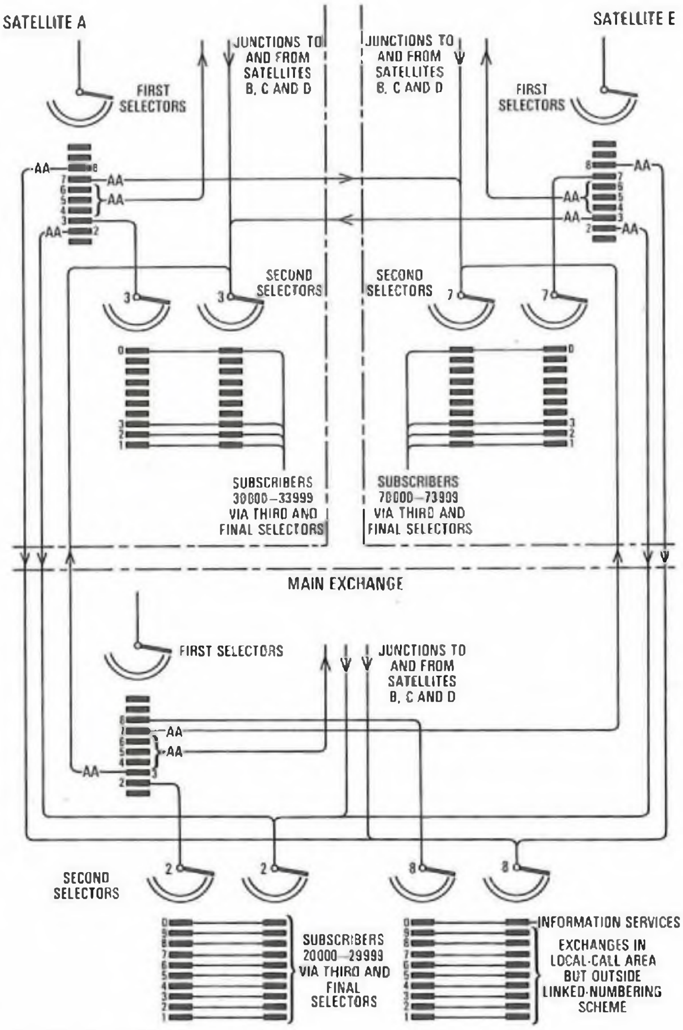
A. 3. (*a*) First-selector levels 1, 8, 9 and 0 are dedicated to specific functions which preclude their use in the subscribers' multiple of a linked-numbering scheme. Typically, level 1 gives access to manual-board services, levels 8 and 9 give access to exchanges in the local-call area but outside the linked-numbering scheme, and level 0 gives access to the STD network. Level 9 also gives access to the emergency services, and level 8 to information services. Therefore, levels 2–7 are available for use in the linked-numbering scheme for a main exchange with 5 satellite exchanges.

If a 4-digit numbering scheme were adopted, each first-selector level would serve 1000 subscribers and, hence, a total of 30 levels would be required for the 30 000 lines. Since only 6 levels are available, it is reasonable to use a 5-digit numbering scheme and, since more subscribers are likely to be connected to the main exchange than any of the satellites, it is convenient to allocate the multiple as shown in the following table.

Exchange	Multiple Size (lines)	Numbering Range
Main	10 000	20 000–29 999
Satellite A	4 000	30 000–33 999
Satellite B	4 000	40 000–43 999
Satellite C	4 000	50 000–53 999
Satellite D	4 000	60 000–63 999
Satellite E	4 000	70 000–73 999

The sketch shows a simplified trunking diagram of the linked-numbering scheme, using group-selector-satellite working. Satellites B, C and D are omitted for clarity, but are similar to satellites A and E. The level-1, level-9 and level-0 services are not required for the purpose of illustrating the linked-numbering scheme, and are also omitted.

(*b*) With reference to the sketch, the following describes the routing of calls from one of the satellites to exchanges inside and outside the linked-numbering scheme.



AA: AUTO–AUTO RELAY SET

Call from Satellite A to Main-Exchange Subscriber (*2XXXX*)

The call is routed from first-selector-level 2 in satellite A, via an auto–auto relay-set and junction, to a level-2 second selector in the main exchange. The second selector gives access to the 10 000 main-exchange subscribers.

Call from Satellite A to Satellite-E Subscriber (*7YYYY*)

The call is routed from first-selector-level 7 in satellite A, via an auto–auto relay-set and junction, to a level-7 second selector in satellite E. The second selector gives access to the 4000 satellite-E subscribers.

Calls from Satellite A to Exchanges outside the Linked-Numbering Scheme

Callers consult dialling-code lists to ascertain the code required to reach the destination exchange. For an exchange having a dialling code in the range 80–89, calls are routed from first-selector-level 8 in satellite A, via an auto–auto relay-set and junction, to a level-8 second selector in the main exchange. The second selector gives access to junctions to the desired exchange. Exchanges having dialling codes commencing with the digit 9 are similarly accessed, using level-9 second selectors in the main exchange. Level-0 (STD) calls are routed directly to a register-access relay-set in the main exchange (see A.2 of this examination paper).

Q. 4. (*a*) *Draw a subscriber's uniselector line-circuit.*

(*b*) *Describe the circuit operation on*

(*i*) *a call originated by the subscriber, and*

(*ii*) *a call received by the subscriber.*

(*c*) *How would your answers to parts* (*b*) (*i*) *and* (*b*) (*ii*) *be modified, if, due to a fault, the winding of the cut-off relay* (*relay K*) *were disconnected?*

Q. 5. (*a*) *Describe the essential differences between PBX final selectors designed to serve*

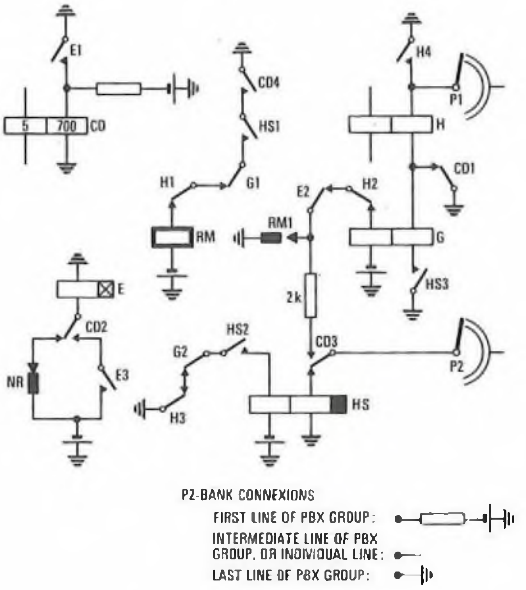
(*i*) *small groups of PBX lines, and*

(*ii*) *large groups of PBX lines.*

(*b*) *Select one of the above and, with the aid of a sketch of the circuit elements concerned, describe the circuit operation whilst hunting for, and switching to, a disengaged line.*

A. 5. (*a*) (*i*) Groups of 2–10 PBX lines are served by 2–10 PBX final selectors, which also cater for individual lines. On any level, lines and groups of lines may be mixed, within the limit of a total of 10 lines. The rotary action of the 2–10 PBX final selector is controlled by the calling-subscriber's dial. Hunting action, over the lines of a PBX group, commences only if the final selector is rotarily stepped to the first line of that group. The 200-outlet version of this type of final selector serves 2 group-selector levels, using a wiper-switching arrangement, and all lines are within the exchange's numbering scheme.

(*ii*) Larger groups of PBX lines are served by 11-and-over PBX final selectors. An 11-and-over PBX final selector provides for 200 lines, each level serving 20 lines, 10 of which are hypothetical; that is, outside the exchange's numbering scheme. The final digit is absorbed, and the hunting action commences after the penultimate digit is received. Hence, a minimum of one level is allocated to each PBX subscriber. For subscribers with more than 20 lines, additional levels are allocated. After stepping over 20 busy lines in a PBX group, the final selector steps vertically, under the control of signals from a vertical marking bank, to the next level belonging to that group. The selector cannot be stepped under dial control to intermediate lines of a PBX group, and special arrangements have to be made for night service.



(*b*) The sketch shows the hunting and switching circuit elements of a 2–10 PBX final selector.

After receipt of the final digit, relay CD releases. Contact CD1, releasing, offers relay H to the P-wire of the called line, via the P1-wiper, for testing purposes. Contact CD2, releasing, disconnects relay E, which releases slowly. (Note that rotary off-normal contacts NR are operated at this stage, since rotary stepping has taken place.) If the line is free, relay H operates to the 1300 Ω battery free condition during the slow release of relay E. If the line is busy, relay H does not operate.

If the line is the first of a PBX group, the P2-wiper encounters a resistance-battery condition, which operates relay HS. Contact HS2 provides a holding circuit for relay HS.

After the slow release of relay E, contact E1, releasing, removes a short-circuit from relay CD, which re-operates. Assuming the first line to be busy, contact CD4 completes an energizing circuit for the rotary selector-magnet (RM). Magnet RM operates, causing the wipers to step to the next outlet (the second line of the PBX group) and interrupter contact RM1 to operate. Interrupter contact RM1 operates relay G, and contact G1 disconnects the energizing circuit of magnet RM, which releases.

Relay H is again offered to the P-wire, in series with pre-operated relay G, from the earth at contact HS3. If the line is free, relay G holds to the 1300 Ω battery condition, and relay H operates. Contact H1 prevents the re-energization of magnet RM when contact H2 releases relay G, and contact H3 disconnects relay HS. Ringing current is then applied to the line, and ringing tone is returned to the calling subscriber.

If the second line is also busy, there is no holding path for relay G. Relay G releases and contact G1, releasing, re-energizes magnet RM. The selector continues to step under the interaction between magnet RM, interrupter contact RM1 and relay G for as long as busy conditions are encountered on consecutive lines. Relay HS holds during operations of relay G due to its slow-to-release feature. When a free line is reached, relay G holds, and the hunting action is arrested as described above.

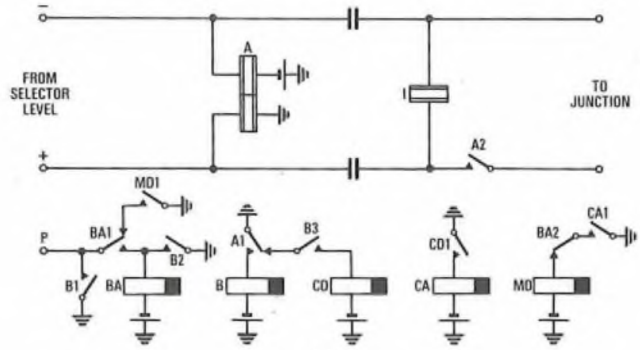
If all the lines in the PBX group are busy, a holding circuit for relay G is provided on the last line of the group by an earth on the P2-bank contact. Relay H does not operate, and relay HS releases slowly. Busy tone is returned to the calling subscriber.

Q. 6. With the aid of sketches of the circuit elements concerned, explain how

(a) a junction between 2 automatic exchanges is guarded against premature reseizure immediately following a call, and

(b) similar guarding is achieved in the case of an exchange line serving a PABX. (Consider only calls originated at the PABX.)

A. 6. (*a*) Sketch (*a*) shows the circuit elements of an auto-auto relay-set concerned with guarding a junction against premature reseizure.

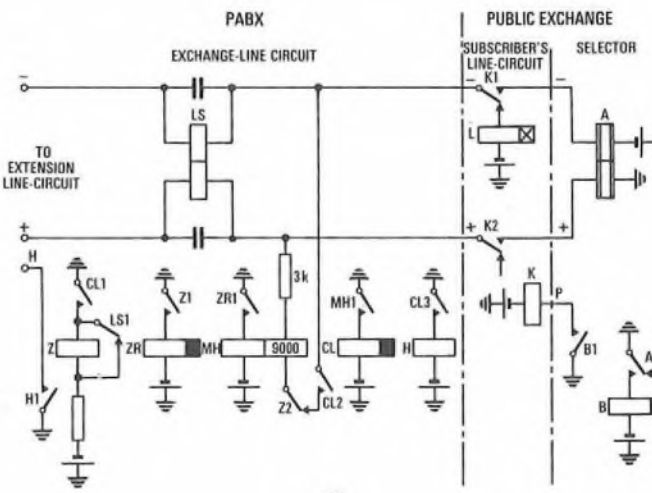


(*a*)

When the calling subscriber clears down following a call, relay A releases. Contact A2, releasing, disconnects the forward loop holding the selectors at the distant exchange, thus initiating their release. Contact A1, releasing, disconnects relay B and operates relay CD. Contact CD1 operates relay CA. A slow-to-release relay sequence commences, giving a time interval slightly longer than that required for the complete release of the selectors at the distant exchange.

Contacts B1 and B2, releasing, remove the holding earth from the incoming P-wire and disconnect relay BA. During the release time of relay BA (30 ms), the P-wire is open, thus allowing the preceding equipment to release without waiting for the distant equipment to restore fully. At the end of the release lag, contact BA2 operates relay MD, and contact MD1 reguards the P-wire to busy the relay-set and junction until the distant equipment is released. The reguarding period is timed by the release of relay CD (disconnected by contact B3), the release of relay CA (disconnected by contact CD1), and the release of relay MD (disconnected by contact CA1). Contact MD1 finally removes the guarding earth.

(*b*) Sketch (*b*) shows the circuit elements concerned with guarding an exchange line serving a PABX against premature reseizure.



(*b*)

When the calling subscriber clears down following a public-exchange call from a PABX extension, the public-exchange equipment starts to release, and relay LS in the exchange-line circuit at the PABX releases. At this stage, relays Z, ZR, MH, CL and H are operated. Contact LS1 short-circuits relay Z, which releases. Contact Z1 disconnects relay ZR, which releases slowly. Contact Z2 connects the high-resistance (9 kΩ) coil of relay MH across the line.

The subscriber's line-circuit at the public exchange serving a PABX line is modified by disconnecting the earth from the break spring of contact K2 on the positive wire. Hence, relay MH remains held for as long as the release of relay K in the subscriber's line-circuit is delayed; that is, during the release of the public-exchange selectors. When relay K releases, so does relay MH. Contact MH1 then disconnects relay CL, which releases slowly, and contact CL3 disconnects relay H. Contact H1, releasing, then removes the guarding earth from the H-wire, marking the exchange-line circuit as being free. Thus, the exchange-line circuit is guarded until after the public-exchange equipment has restored.

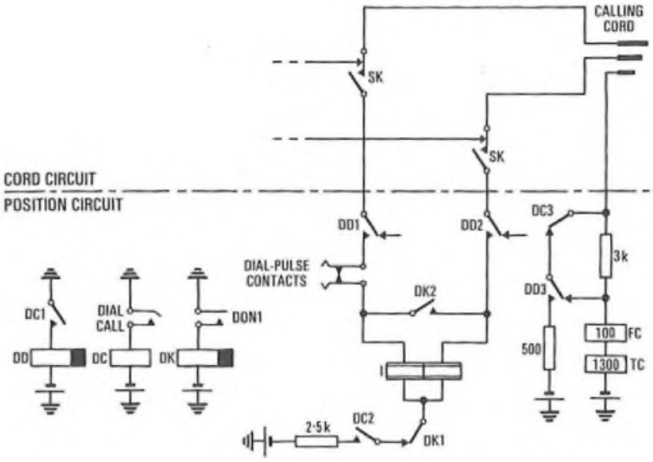
Q. 7. (*a*) *With the aid of sketches of the circuit elements concerned, explain how the following signals are generated within the position circuit of a sleeve-control switchboard:*

(*i*) *dialling about to commence, and*

(*ii*) *end of dialling.*

(*b*) *What facilities of the line-terminating relay-set are controlled by the above signals?*

A. 7. (*a*) The sketch shows the elements of a sleeve-control-switchboard's position circuit concerned with the generation of signals associated with the DIAL CALL key.



(*i*) When the DIAL CALL key is operated, relay DC operates, and contact DC1 operates relay DD. Contacts DD1 and DD2 connect the tip and ring wires of the calling cord, via retarding coil I and a 2·5 kΩ resistance, to battery. Contact DC3, operating, increases the resistance of the sleeve wire by 3 kΩ. The *dialling-about-to-commence* signal, which informs the line-terminating relay-set that the DIAL CALL key has been operated, is, therefore, a balanced resistive battery on the tip and ring wires. During dialling, dial-off-normal contact DON1 operates relay DK, contact DK1 disconnects the balanced-battery conditions, and contact DK2 provides a dialling loop.

(*ii*) When the DIAL CALL key is restored, relay DC releases, and contact DC1 disconnects relay DD. Relay DD is slow to release and, during its release lag, contact DC3 connects a 500 Ω battery condition to the sleeve wire. This condition is disconnected by contact DD3. The *end-of-dialling* signal, which informs the line-terminating relay-set that the DIAL CALL key has been restored, is, therefore, a momentary lowering of the sleeve-wire resistance.

(*b*) The balanced-battery *dialling-about-to-commence* signal operates a relay in the line-terminating relay-set which rearranges the relay-set's transmission bridge to remove all shunt and series elements from the dialling path.

On receipt of the *end-of-dialling* signal, the increased current resulting from the decrease in sleeve-wire resistance is used to operate a relay which restores the relay-set's transmission bridge. Normal holding and speaking conditions are established, and the relay-set is ready to detect answering conditions.

Q. 8. (*a*) *Draw a trunking diagram of a Strowger local director exchange.*

(*b*) *Describe the sequence of operations on calls to*

(*i*) *own-exchange numbers, and*

(*ii*) *an assistance operator.*

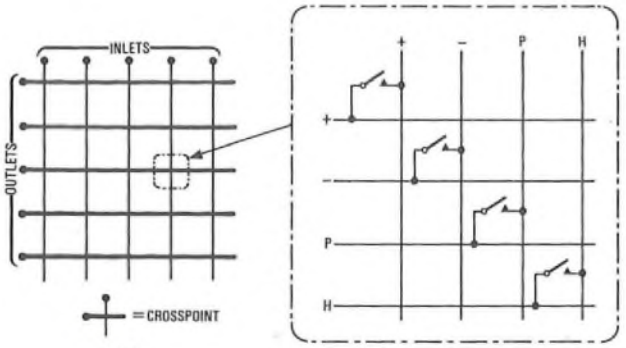
(*c*) *What sequence of operations results if a calling subscriber dials an unused exchange code?*

Q. 9. (*a*) *Explain how a number of reed relays may be arranged to produce a matrix-switching array.*

(*b*) *Explain how a number of matrix arrays may be interconnected to provide alternative paths between any 2 subscribers on a TXE2 reed-relay exchange.*

(*c*) *Give one example where a connexion path between a given pair of subscribers would not be available.*

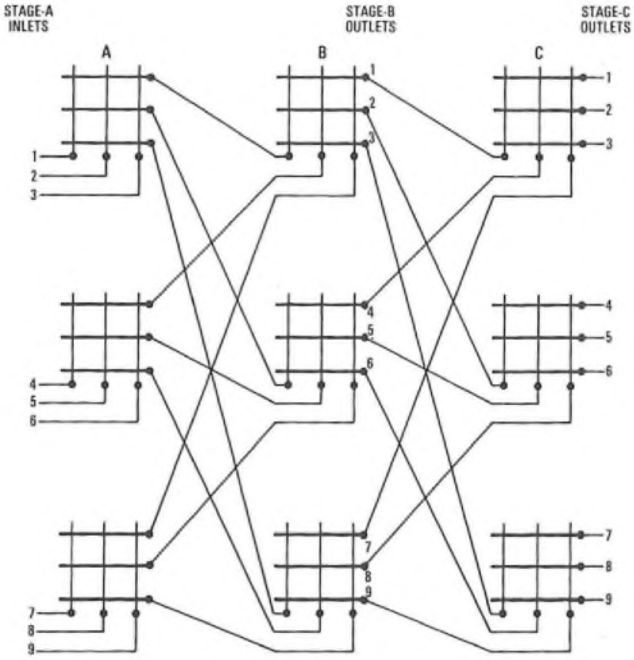
A. 9. (*a*) Sketch (*a*) represents a co-ordinate array of reed-relay contacts known as a crosspoint matrix. Each horizontal and vertical line represents a 4-wire circuit, and at each intersection (or crosspoint) there is a group of 4 reed-relay contact units, as shown in sketch (*b*).



(*a*) (*b*)

The 4 contact units are enclosed in one winding, forming a single reed relay. Thus, the crosspoint matrix shown in sketch (*a*) consists of 25 reed relays, and is known as a 5 × 5 matrix. Other matrix sizes are possible; for example, a 4 × 3 matrix requires 12 reed relays.

(*b*) Sketch (*c*) shows a simplified 3-stage system of matrices illustrating the principle of interconnexion used in a TXE2 exchange.



(*c*)

A number of possible alternative paths exist for connecting any particular stage-A inlet to any particular stage-C outlet. Internal blocking, or link congestion (see part (*c*)), affecting any individual matrix, is circumvented by the use of an alternative path. For example, to connect inlet A1 to outlet C1, there are 3 possible paths: via stage-B outlets B1, B4 or B7.

(*c*) Consider a 2-stage system of matrices, such as that consisting of stages A and B in sketch (*c*). If inlet A1 is connected to outlet B1, inlets A2 and A3 are prevented from having access to outlets B2 or B3, even though these may be free. This condition is known as *internal blocking* or *link congestion*, and occurs more easily in a 2-stage system than in a 3-stage system, the latter being designed to overcome this problem.

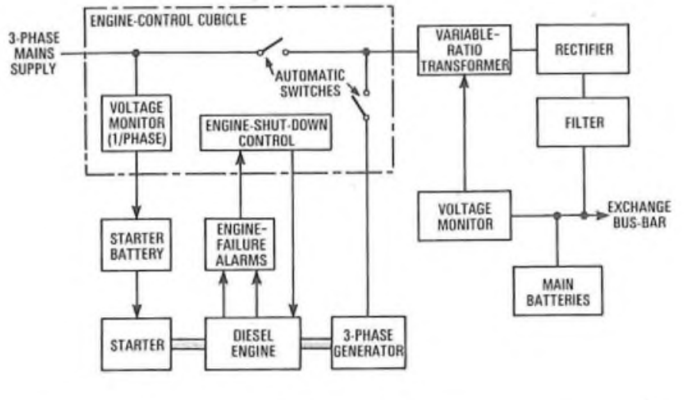
Q. 10. *The power plant for an an exchange of medium size is of the floated-battery type, mains powered, and includes a fixed stand-by engine set.*

(*a*) *Draw a block diagram of the system.*

(*b*) *Give an outline description of the engine set and its principal auxiliary equipment.*

(*c*) *What considerations determine the capacity of the main battery?*

A. 10. (*a*) The sketch shows a block diagram of a floated-battery, mains-operated power plant with a fixed stand-by engine set.



(*b*) A description of the operation and arrangement of the engine set and its auxiliary equipment is given below.

If the voltage monitor in the engine-control cubicle detects an unacceptable fall in mains voltage, it causes the starter battery to drive the starter. The Diesel engine starts and drives the generator. When the engine reaches its working speed, the mains supply is disconnected and the generator's output is substituted, by means of automatic switches in the engine-control cubicle.

Fuel for the engine is normally supplied from an underground storage tank, and cooling water from a further storage tank. The engine exhausts to the atmosphere. The engine temperature and oil pressure are continuously monitored, and malfunctions are signalled to the engine-control cubicle which shuts-down the engine. If the engine fails to start, or stops for any reason, an alarm condition is extended to the nearest attended exchange, and the local-exchange power supply is taken over by the main batteries.

When the mains voltage returns to normal, the mains supply is reconnected, but the engine continues to run for a period sufficient to ensure that the starter battery is recharged.

(*c*) If an exchange is provided with a fixed stand-by engine set, the main batteries are not called upon to supply power unless both the mains supply and the engine set fail simultaneously. The battery's capacity can, therefore, be relatively small. Typically, it is sufficient to be able to maintain the exchange's peak load for a period of 3 h.

The peak load consists of a small miscellaneous load, approximately proportional to the number of exchange lines, plus a switching load due to the busy-hour traffic. For each switching stage, the average current taken by a selector carrying traffic is known, and so is the average number of simultaneous calls (the busy-hour traffic flow in erlangs). The product of these 2 factors gives the current load in amperes for that switching stage.

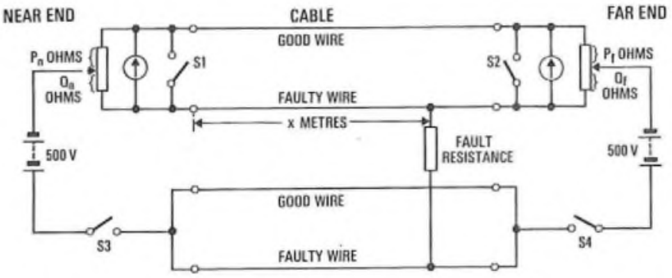
LINE PLANT PRACTICE B, 1974

Students were expected to answer any 6 questions

Q. 1. *(a) Describe, with the aid of a diagram, how a double-ended Murray test is used for locating a low-insulation-resistance fault on a length of cable.*

(b) In such a test on a cable 860 m long, the near-end and far-end resistance readings are 810 Ω and 654 Ω respectively. How far is the fault from the near end?

A. 1. (*a*) A double-ended Murray test, using identical apparatus at each end of the cable, can be used for locating low-insulation-resistance faults. The apparatus is connected as shown in the sketch, and consists, essentially, of two 1000 Ω potentiometers, one at each end of the cable. The test is made as follows.



(*i*) Negative battery is applied to charge the line, from the near end, by closing switch S3, switch S4 remaining open. Switch S2 is closed at the far end to complete the circuit, switch S1 remaining open.

(*ii*) The line is allowed to charge up, and the potentiometer at the near end is then adjusted to give zero deflexion on the galvanometer. After a time, the resistance value, P_n ohms, required to maintain zero deflexion, becomes constant, and this value is noted.

(*iii*) A similar test is then made at the far end, by closing switches S4 and S1, and opening switches S3 and S2. The far-end potentiometer is adjusted for zero deflexion of the galvanometer, and resistance value P_f ohms is recorded.

(*iv*) Tests are repeated several times to obtain good average values for P_n and P_f, and the distance from the near end to the fault, x metres, is calculated from the formula

$$x = \frac{P_f - Q_f}{(P_n - Q_n) + (P_f - Q_f)} \times l \text{ metres},$$

where

$$Q_n = 1000 - P_n \text{ ohms},$$
$$Q_f = 1000 - P_f \text{ ohms},$$

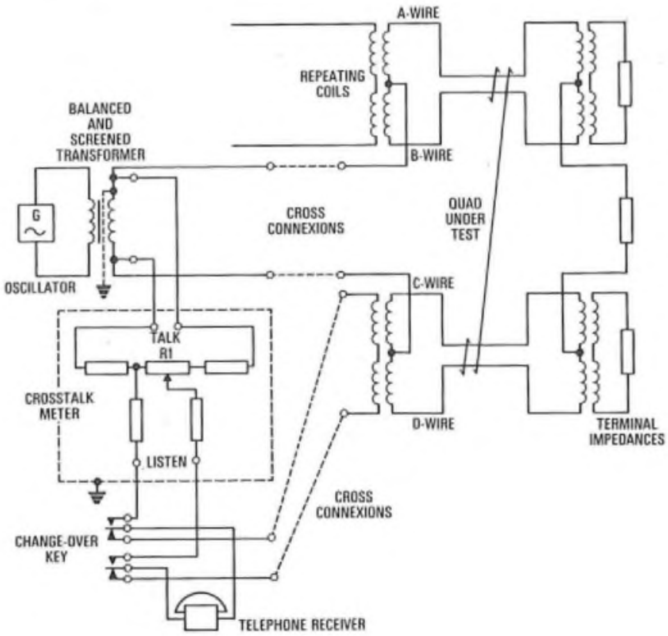
and l is the length of cable under test (m).

(*b*) From the data given, $P_n = 810$ Ω and $P_f = 654$ Ω. Therefore, $Q_n = 190$ Ω and $Q_f = 346$ Ω.

Hence,
$$x = \frac{654 - 346}{(810 - 190) + (654 - 346)} \times 860 \text{ m},$$
$$= \underline{285 \cdot 4 \text{ m}}.$$

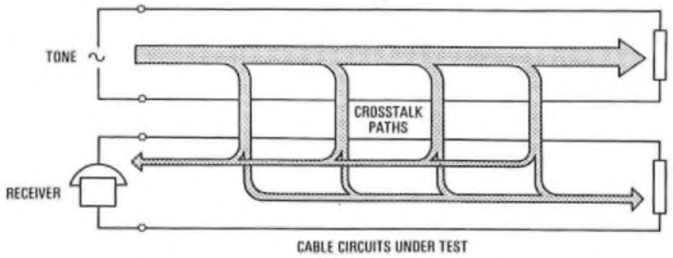
Q. 2. *Describe, with the aid of sketches, how near-end crosstalk measurements are made on a loading section of cable.*

A. 2. To measure near-end crosstalk on a loading section of cable, a crosstalk meter, oscillator, balanced and screened transformer, and repeating coils are connected as shown in sketch (*a*).



(*a*)

The tone from the oscillator is fed to the phantom circuit of the quad under test and to the TALK terminals of the crosstalk meter. The telephone receiver is connected to one of the side circuits and to the LISTEN terminals of the crosstalk meter, via the change-over key. The inductive and electrostatic interference between the phantom and the side circuit, that is, the crosstalk, is heard in the receiver. The magnitude of the crosstalk is compared with the tone heard across the LISTEN terminals of the crosstalk meter by the operation of the change-over key. The receiver is successively connected to the side circuit and to the crosstalk meter, whilst potentiometer R1 is adjusted until the tones from both sources appear to be equal. Potentiometer R1 is calibrated in terms of fractions of the voltage applied to the TALK terminals. Hence, the reading gives the magnitude of the crosstalk as a fraction of the voltage applied to the phantom circuit. Similar tests are then made to determine the crosstalk between other circuits of the quad, and between circuits of different quads.



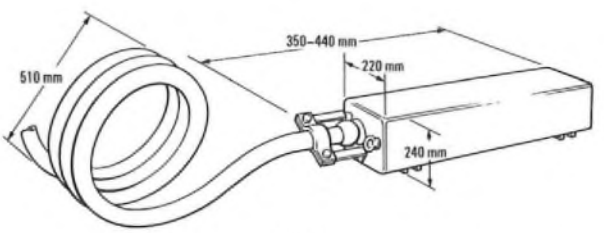
(*b*)

The crosstalk measured is the resultant of all the crosstalk currents arriving via the paths shown in sketch (*b*). Owing to the differing lengths of the crosstalk paths, measurements of near-end crosstalk, made between any 2 particular circuits at each end of a cable, may not give the same result. For this reason, it is usually necessary, except for short cables, to measure near-end crosstalk from both ends.

Q. 3. (a) With the aid of a sketch, describe a single-stub loading-coil case suitable for loading a 104-pair cable.

(b) With the aid of a sketch, show how such a loading case would be positioned and jointed in a joint-box.

A. 3. (*a*) The single-stub loading-coil case for a 104-pair cable is known as the *chamber* type, and is illustrated in sketch (*a*). It is constructed from 5 mm thick steel sheet, with heavier-section mild steel used for the lid, and the lid carries steel pillars and distance pieces which hold the coil assemblies in position. The case is fabricated so that there are no sharp corners, and all joints are arc-welded to provide an effective seal.



(*a*)

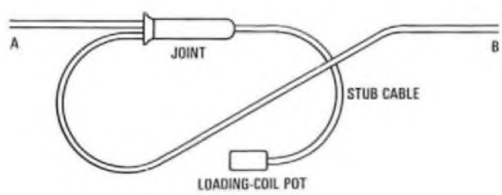
The case is mounted horizontally and intended for use in jointing boxes. It is raised 20 mm clear of the floor by means of I-section or U-section channel. A lifting ring is fitted to enable the assembly to be hoisted for lowering into a jointing box. Where the stub cable passes into the lid, a watertight sleeve is fitted, and a bracket supports the cable and relieves the strain on the epoxy-resin joint between the stub cable and sleeve. One, or 2, holes are provided in the lid so that the case can be filled with compound.

The outside of the case and the external ironwork are thoroughly cleaned and roughened by shot-blasting and, within an hour of blasting, are zinc sprayed to a thickness of 0·13 mm. The case is finally coated with a bituminous compound, reinforced by a tight-fitting, strong, open-weave hessian bag.

Prior to the insertion of the loading coils, the case, complete with its lid, is subjected to an air-pressure or hydraulic-pressure test to a pressure of 140 kPa, to prove that it is free from holes. After the coils have been assembled in the case and the final weld made, an air-pressure test at a pressure of 140 kPa is again applied, the test being made through one of the compound-filling holes and with the free end of the stub cable sealed. Following a satisfactory air-pressure test, impregnating compound is run into the case under pressure, or by a vacuum process. The compound completely covers the coils, wiring and cable-ends within the case, preventing the ingress of moisture.

The stub cable, external to the case, is normally 3 m in length, and is formed into a 510 mm diameter coil which is supported during transit.

(*b*) The loading-coil case's packaging is kept in place for as long as possible up to the time of installation. Care is taken at all times to ensure that the case is not damaged. The chamber-type loading-coil case is laid horizontally on the floor of the jointing box and positioned so that the bending-radius limits for the stub cable are not exceeded. The jointing arrangement is shown in sketch (*b*).



(*b*)

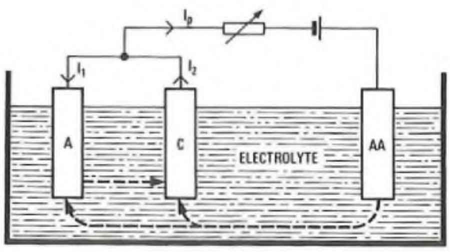
Loaded pairs are routed from A to B via the stub cable and loading-coil pot. Pairs 1–52 of the stub cable are connected to one side of the 54 loading coils in the pot, and pairs 53–104 are connected to the other. Unloaded pairs are through-jointed.

Q. 4. (a) Explain what is meant by cathodic protection.

(b) Describe one method of applying cathodic protection to an underground cable system.

A. 4. (*a*) Cathodic protection is a method of reducing electrochemical corrosion of metallic underground structures by the injection of current into the structure from the surrounding soil.

Corrosion usually occurs at anodic areas on the structure; that is, at areas or points at which the current leaves the structure for the surrounding electrolyte. Generally, there is no corrosion where current enters the structure from the surrounding electrolyte; that is, at cathodic areas. The passage of current in an anodic or cathodic direction is always accompanied by a change in the potentials of the anodes and cathodes involved. This effect is termed *polarization*. At the anodes, polarization causes the electrode potentials to change in a positive direction; at the cathodes, polarization causes the electrode potentials to change in a negative direction. Polarization increases with current density, but the relationship is not linear. Thus, by injecting current into the structure in a cathodic direction, cathodic protection causes the anode and cathode potentials to increase negatively, thereby preventing corrosion of the metal.



The principle of cathodic protection, as applied to non-electrolytic corrosion, is illustrated by the analogous arrangement shown in the sketch. A and C represent the anode and cathode, respectively, of a local cell formed on the surface of an underground structure. Before cathodic protection is applied, the anodic and cathodic currents are equal and flow in the electrolyte from A to C. Under these conditions, current I_1 is the corroding current, and corrosion occurs at the anode. If a third electrode, AA, is connected to the structure, and the protection current, I_p, is caused to flow in the direction shown, current I_2 is increased and current I_1 is reduced. The cathode, therefore, polarizes to a more-negative potential, and the anode potential returns towards its unpolarized negative value. If the value of I_p is sufficient to polarize the cathode to the most-negative natural potential of the anode, then corrosion is prevented.

(*b*) One practical method of applying cathodic protection is to use reactive anodes of magnesium. These have a more-negative natural electrode potential than the anodes of the structure to be protected. They supply the polarizing current in the process of their own corrosion. The magnesium anodes are buried in the ground and connected to the structure by an insulated wire. This method is used only where the required protecting current is small.

Q. 5. (a) Explain the term fineness modulus as applied to the aggregate used in a concrete mix.

(b) Describe in detail how the fineness modulus of an aggregate is measured.

(c) What are the practical limits for fine, coarse and combined aggregates?

A. 5. (*a*) The fineness modulus is a method of representing the grading of an aggregate by means of a numerical value. Its significance in the design of concrete mixes is that it enables some measure of control to be exercised over the grading of the aggregate used. The grading, or proportion of the various sizes of particles in an aggregate, is of importance because it affects the workability of the concrete. The maximum suitable size of an aggregate is controlled by the nature of the work; for example, in thin slabs or walls, the largest size of aggregate should not exceed about 0·2–0·25 times the thickness of the concrete. For reinforced-concrete work, the maximum size of coarse aggregate in normal situations is 19 mm, although larger aggregates are frequently used in road construction.

The fineness modulus is a useful means of comparing the gradings of 2 aggregates, so long as they are of a somewhat similar type. Thus, it can be effectively used to record any variation in the grading of aggregates used for a particular application. If, however, the sizes of particles in a sample of aggregate are very dissimilar, the fineness modulus is not a good guide to the concrete-making properties of the aggregate.

(*b*) To measure the fineness modulus of an aggregate, it is first necessary to obtain a representative sample of the aggregate, and the method of *quartering* is best employed. The aggregate is spread out evenly on a clean surface to a depth of about 75 mm. It is then divided into 4 equal parts, and 2 diagonal quarters are discarded. The remainder is mixed and again quartered. This procedure is continued until a sample of about 10 kg remains. The sample is then carefully dried, cooled and weighed, after which it is passed successively through 9 sieves having decreasing aperture sizes. The material retained on each sieve, together with any material cleaned from the mesh, is weighed and recorded, as shown in the table below, which gives the results for a typical 9·6 kg sample. The weight of aggregate passing each sieve, and its relationship to the sample, is then calculated.

Sieve-Mesh Size (mm)	Weight Retained on Sieve (kg)	Weight Passing Sieve (kg)	Percentage Passing Sieve (%)	Percentage Retained on Sieve (%)
38	0	9·6	100	0
19	0·24	9·36	97	3
9·5	5·52	3·84	40	60
4·8	3·36	0·48	5	95
2·4	0·48	—	0	100
1·2	—	—	0	100
0·6	—	—	0	100
0·3	—	—	0	100
0·15	—	—	0	100
				Total: 658

The fineness modulus is calculated by adding up the cumulative percentages of the aggregates retained on each sieve and dividing by 100. In the case of the aggregate sample in the table,

$$\text{fineness modulus} = \frac{658}{100} = \underline{6 \cdot 58.}$$

(*c*) The practical limits of the fineness modulus are, for fine aggregates, 2–3·5; for coarse aggregates, 5·5–8; and for combined fine and coarse aggregates, 4–7.

Q. 6. *Describe how subscribers'-line development forecasts are made.*

A. 6. A subscribers'-line development forecast takes the form of a field survey and a forecast of demand for exchange connexions and miscellaneous circuits. Forecasts are made for 4 *base dates*, occurring at intervals of 5 years, and must take account of the varying distribution of demand in the telephone area for this 20-year period.

The field survey of a telephone-exchange area is carried out to

(*a*) determine the potentialities of land and buildings and to forecast their probable future use,

(*b*) ascertain the probable commercial, industrial and residential development and to estimate the resulting demand for telephone lines, and

(*c*) to record the number of tenancies—that is, houses, flats, businesses and shops—existing and expected.

To gather the required information, contacts are made with local builders, estate agents, property developers and local-government planning authorities. The survey is carried out with the aid of large-scale Ordnance Survey maps. The whole area is divided into small sections, and the individual forecasts for these sections are totalled to give the exchange-area forecast. The sections are so divided that the potential residential telephone demand is uniform. The tenancies within the sections are divided into either business or residential categories. When a building, such as a block of flats or a factory, interrupts the otherwise uniform telephone penetration of a section, a sub-section is formed and a separate forecast made.

An exchange area generally consists of the following 3 different types of territory:

(*a*) commercial and/or industrial,
(*b*) built-up residential, and
(*c*) outer rural fringe.

Business tenancies are determined separately from residential tenancies. The residential property may be of varying types and, therefore, the number of estimated connexions at the end of the 20-year forecast period is determined by the *telephone penetration factor* of each type, where

$$\text{telephone penetration factor} = \frac{\text{total number of connexions}}{\text{total number of tenancies}}.$$

Separate forecasts are made for each large business, and a total forecast is made for all the small businesses, in each section. Additionally, forecasts are made for miscellaneous circuits, such as Telex circuits and private wires.

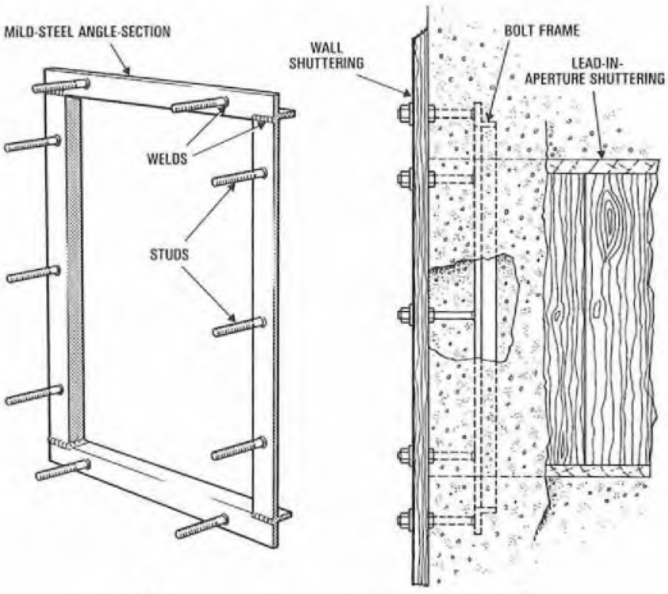
Forecasts are made in the light of current policy and the reasonable expectation of certain social and economic changes taking place during the forecast period. All the information is recorded on field-survey sheets, which, with the data recorded on the Ordnance Survey maps, form the development study.

Q. 7. (*a*) *With the aid of a sketch, describe in detail one method of sealing empty PVC ducts to prevent the entry of gas and water into a cable chamber.*

(*b*) *Describe how a polyethylene-sheathed cable is sealed in a PVC duct forming part of a lead-in.*

A. 7. (*a*) The sealing of empty PVC ducts to prevent the entry of water and gas into a cable chamber is achieved by clamping a PVC sheet to the duct-lead-in aperture, with each duct individually terminated in a caulking gland secured to the sheet.

At the time of construction of the cable chamber, a bolt frame is cast within the wall around the lead-in aperture, the size of the bolt frame being directly related to the number of ducts to be laid and their formation. Sketch (*a*) shows the arrangement of 50 × 38 × 6 mm mild-steel angle-section and 12 mm diameter threaded studs which form the bolt frame, and sketch (*b*) shows the bolt frame cast into position during construction of the chamber. The studs are used to bolt the frame temporarily to the wall shuttering, enabling the frame to be correctly positioned a depth of 100 mm in the concrete.



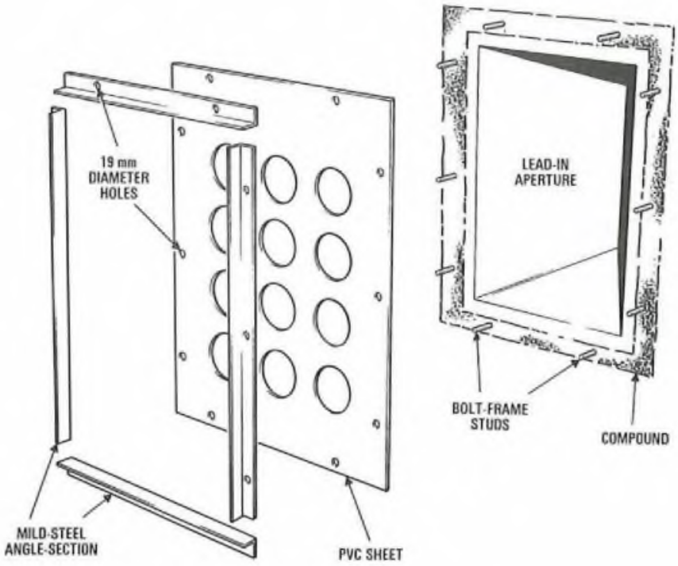
(*a*) (*b*)

When duct-laying is about to commence, a pre-cut and pre-drilled PVC sheet is clamped to the lead-in aperture with strips of mild-steel angle-section, using the threaded studs of the bolt frame cast into the wall. Prior to fixing the PVC sheet, a 76 mm wide strip of compound is placed on the wall around the aperture, and centred on the studs, as a bedding material. Sketch (*c*) illustrates the arrangement.

The assembly of a caulking gland is shown in sketch (*d*). The gland, collar, lock-nut and end-cap are plastics mouldings, and rubber ring washers are used. The caulking gland and collar are fitted to the PVC sheet with the end-cap omitted, and the lock-nut is firmly tightened with a special spanner. If necessary, the lead-in may be angled at 5°, 10° or 15° by the use of angled collars.

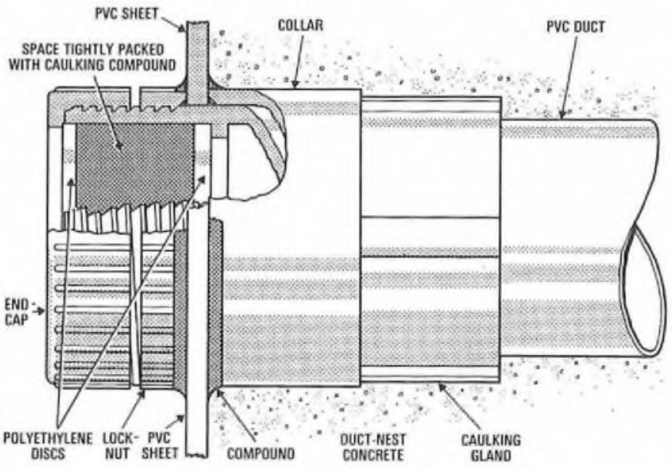
The spigot of the duct and the inside of the gland are cleaned with methylated spirits, and the spigot is liberally coated with a solvent adhesive for a distance of 127 mm. The spigot is then immediately pushed into the gland until the end of the duct butts against the internal shoulder of the gland. All the first lengths of PVC duct are laid in this way, and they are always laid straight, so that the PVC sheet is not distorted. Where 12 or more lead-in ducts are laid, it is necessary to strut the PVC sheet from within the building while the duct-nest is being concreted, to prevent distortion.

On completion of duct-laying between the cable chamber and the lead-in jointing chamber, the ducts are cleaned and tested, and draw-



(*c*)

ropes are left in them. To seal an uncabled gland, a polyethylene caulking disc, which fits inside the gland, has two 6 mm diameter holes drilled in it, diametrically opposite and 12 mm from the outer edge. The draw-rope is knotted approximately 150 mm from its end, passed through one hole and back through the other hole, and a second knot is made at the end of the draw-rope. The disc is then placed at the back of the gland, with the 2 knots at its rear, and surplus draw-rope is pushed up the duct. The loop of rope left at the front of the disc facilitates its easy removal. The gland is then tightly filled with a dense compound until it is slightly over-filled, and a second caulking disc is positioned on its end. The end-cap is screwed on, compressing the compound; the effectiveness of the gland as a seal against water and gas is dependent upon the compound being under compression.



(*d*)

(*b*) To cable an empty duct, the end-cap, caulking discs and compound are removed from the gland, the end-cap being replaced to prevent frictional wear on the inside of the gland due to the cabling rope. Following the cabling operations, the end-cap is removed and the caulking discs drilled or cut to fit snugly over the cable or cables. If the cable is of small diameter, and there is a likelihood of further cable being pulled into the same duct, a draw-rope is left in the duct and secured to the rear disc, as described above. The rear disc is positioned at the back of the gland, the gland refilled with compound, and the front disc repositioned and the end-cap screwed on, ensuring that the compound is under compression. Where a large-diameter cable is drawn into an empty duct, and future cabling is impossible, additional support, to keep the cable positioned centrally within the gland, may be provided by replacing most of the compound with rubber rings.

Q. 8. *With the aid of a sketch, describe fully the mechanical design of a 60 m self-supporting steel tower for dish aerials. Include details of the foundations and steel members.*

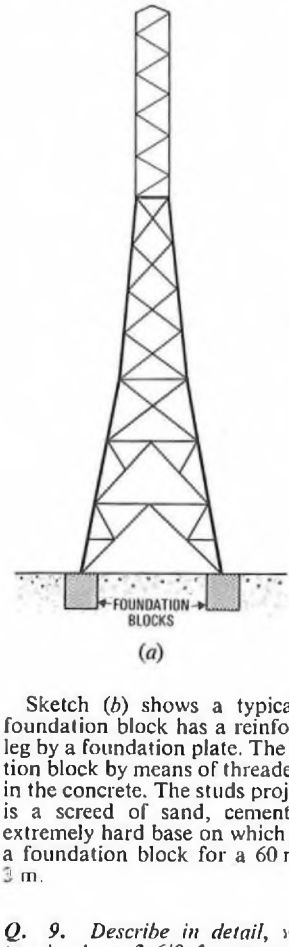
A. 8. A 60 m self-supporting tower is normally constructed from L-section mild-steel members bolted together. A tower of this type is illustrated in sketch (*a*). The tower consists of 4 main posts secured to individual foundation blocks, which are spaced to give an adequate base. The main posts are inter-connected by diagonal external bracings, and strengthened by horizontal external bracings and internal cross-bracings, spaced at intervals throughout the tower.

The top of the tower is reinforced by 4 mild-steel corner plates, and is surmounted by 2 lengths of L-section mild steel, bolted together, supporting a gusset plate at each end.

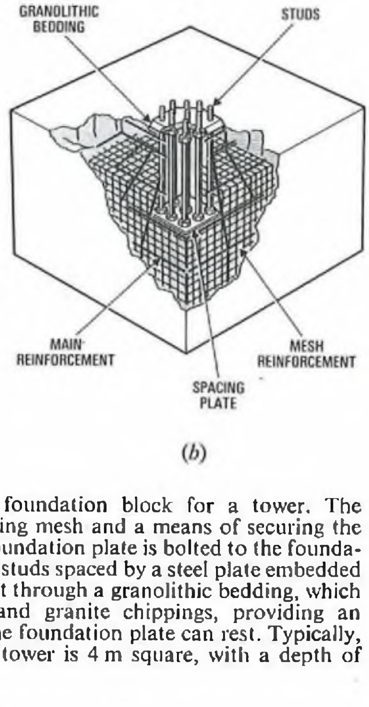
The external bracing takes the form of single-diagonal and double-diagonal bracing, with K-type bracing used at the base.

The size of the mild-steel angle-section used for the bracing and main leg members may be reduced in size towards the top of the tower. For example, a tower can have leg members of 150 × 150 × 16 mm, reducing to 90 × 90 × 12 mm towards the top. The complementary bracing members would range from 90 × 90 × 10 mm to 65 × 65 × 6 mm angle-sections.

For the foundations of the tower, individual concrete blocks may be used in firm soil, provided the blocks are spaced sufficiently apart. Where the ground is less stable, or the legs have little spread, a concrete slab is used. In soft ground, or where the tower is tall, greater resistance to overturning is given by driving piles. The piles are topped by concrete blocks, to which the legs are secured.



(*a*)



(*b*)

Sketch (*b*) shows a typical foundation block for a tower. The foundation block has a reinforcing mesh and a means of securing the leg by a foundation plate. The foundation plate is bolted to the foundation block by means of threaded studs spaced by a steel plate embedded in the concrete. The studs project through a granolithic bedding, which is a screed of sand, cement and granite chippings, providing an extremely hard base on which the foundation plate can rest. Typically, a foundation block for a 60 m tower is 4 m square, with a depth of 3 m.

Q. 9. *Describe in detail, with the aid of a sketch, a method of terminating a 2·6/9·5 mm coaxial pair.*

A. 9. See A.5, Line Plant Practice B, 1971, *Supplement*, Vol. 65, p. 49, Oct. 1972.

Q. 10. (*a*) *Describe how resistance unbalance is measured in a loading section of a cable after laying.*

(*b*) *A test produces the following conductor-resistance measurements on a quad bunched at the distant end:*

$$A + B = 110{\cdot}32\ \Omega,$$
$$A + C = 110{\cdot}10\ \Omega,$$
$$B + C = 110{\cdot}20\ \Omega,$$
$$C + D = 110{\cdot}06\ \Omega.$$

Calculate the resistance unbalance for pairs AB and CD.

A. 10. (*a*) Resistance unbalances in a loading section of cable are measured on all quads using a precision Wheatstone bridge. As the main object of the unbalance test is to detect high-resistance faults, the testing current must be as low as possible, since heavy currents often temporarily seal dry joints. The loop resistance of the AB and CD pairs of each quad is measured on the bridge after bunching the quad at the distant end.

Single-wire resistance and, consequently, resistance unbalance between the wires of a pair, can be determined by the 3-wire method, so named because a minimum of 3 loop measurements are necessary to find the resistance of any single wire. To find the resistance unbalance for the AB and CD pairs of a quad, the loop-resistance measurements of the A + B, A + C, B + C and C + D wires are made and, from these, the resistance unbalance between the wires of the AB and CD pairs can be calculated.

(*b*) $A + B = 110 \cdot 32\ \Omega$, ... (1)

$A + C = 110 \cdot 10\ \Omega$, ... (2)

$B + C = 110 \cdot 20\ \Omega$, ... (3)

$C + D = 110 \cdot 06\ \Omega$. ...... (4)

Adding equations (1) and (2) gives

$2A + B + C = 220 \cdot 42\ \Omega$. ...... (5)

Subtracting equation (3) from equation (5) gives

$$2A = 220 \cdot 42 - 110 \cdot 20\ \Omega,$$
$$= 110 \cdot 22\ \Omega.$$
$$\therefore A = 55 \cdot 11\ \Omega.$$

Hence, from equation (1),

$$B = 55 \cdot 21\ \Omega.$$

Thus, for pair AB, the unbalance

$$= 55 \cdot 21 - 55 \cdot 11 = \underline{0 \cdot 10\ \Omega.}$$

From equation (2),

$$C = 110 \cdot 10 - 55 \cdot 11\ \Omega,$$
$$= 54 \cdot 99\ \Omega.$$

Hence, from equation (4),

$$D = 55 \cdot 07\ \Omega.$$

Thus, for pair CD, the unbalance

$$= 55 \cdot 07 - 54 \cdot 99 = \underline{0 \cdot 08\ \Omega.}$$

COMPUTERS B, 1974

Students were expected to answer any 6 questions

Q. 1. (*a*) *Consider the following denary expression:*

$$13 \cdot 875_{10} + 127 \cdot 1875_{10}.$$

Convert the 2 numbers into binary form, add them together and convert the result back to denary form.

(*b*) *Convert the following denary numbers into binary-coded-decimal (BCD) form, weighted $84\bar{2}1$:*

(*i*) *5796, and*
(*ii*) *425·78.*

A. 1. (*a*) To convert the denary (that is, decimal) numbers, 13·875 and 127·1875, into binary form, the integral and fractional parts are considered separately. The integral part is repeatedly divided by 2, the remainders being noted in reverse order, and the fractional part is repeatedly multiplied by 2, the resulting integers being noted in their correct order.

Integral Part		Fractional Part	
Quotient	Remainder	Integer	Product
13 ÷ 2			0·875 × 2
6	1	1	0·750
3	0	1	0·500
1	1	1	0·000
0	1		

Hence, $13 \cdot 875_{10} = 1\,101 \cdot 111_2$.

Integral Part		Fractional Part	
Quotient	Remainder	Integer	Product
127 ÷ 2			0·1875×2
63	1	0	0·3750
31	1	0	0·7500
15	1	1	0·5000
7	1	1	0·0000
3	1		
1	1		
0	1		

Hence, $127 \cdot 1875_{10} = 1\,111\,111 \cdot 001\,1$.

The binary addition of these 2 numbers is shown below.

```
          0 001 101·111 0
          1 111 111·001 1 +
Carry:   11 111 111·110
Sum:     10 001 101·000 1
```

Hence, $1\,101 \cdot 111_2 + 1\,111\,111 \cdot 001\,1_2 = 10\,001\,101 \cdot 000\,1_2$.

To convert the resulting binary number into its equivalent denary number, it is necessary to multiply each binary digit by its weight and sum the results.

Weight	Binary Digit	Result
$2^7 = 128$	1	128
$2^6 = 64$	0	0
$2^5 = 32$	0	0
$2^4 = 16$	0	0
$2^3 = 8$	1	8
$2^2 = 4$	1	4
$2^1 = 2$	0	0
$2^0 = 1$	1	1
$2^{-1} = 0 \cdot 5000$	0	0
$2^{-2} = 0 \cdot 2500$	0	0
$2^{-3} = 0 \cdot 1250$	0	0
$2^{-4} = 0 \cdot 0625$	1	0·0625

Hence, $10\,001\,101 \cdot 000\,1_2 = (128 + 8 + 4 + 1 + 0 \cdot 0625)_{10}$,

$$= \underline{141 \cdot 0625_{10}}.$$

(*b*) The conversion between decimal form and BCD form, weighted $84\bar{2}1$, is shown in the following table. For a BCD system with this weighting, 4 binary digits are required to represent each decimal digit, the binary digits being weighted such that the least significant has the decimal value 1, the second significant the value 2, the third the value −4, and the most significant the value 8.

Decimal Form	BCD Form, Weighted $8\bar{4}21$
0	0000
1	0001
2	0010
3	0011
4	1100
5	1101
6	1110
7	1111
8	1000
9	1001

(*i*) From the table,

$$\underline{5796_{10} = 1101\,1111\,1001\,1110_{BCD84\bar{2}1}}.$$

(*ii*) Similarly,

$$\underline{425 \cdot 78_{10} = 1100\,0010\,1101 \cdot 1111\,1000_{BCD8\bar{4}21}}.$$

Q. 2. (*a*) *Explain the meaning of the term 2's complement, and say why it is used in digital computers.*

(*b*) *Produce the one's complement and 2's complement of the following binary numbers:*

(*i*) *110 101 110, and*
(*ii*) *111 000.*

(*c*) *Solve the following problem using 2's-complement arithmetic:*

$$110\,111_2 - 1\,101_2.$$

A. 2. (*a*) The 2's complement of a binary number is that number which, when added to the original number, results in an all-zeros answer and a carry from the left-most bit. The 2's complement is obtained by finding the one's complement and adding 1. The one's complement is obtained by inverting each bit of the original number.

Two's-complement arithmetic is used in computers because it simplifies the process of subtraction. The 2's complement of a number is a convention used for representing negative numbers. Each number is assigned a sign bit: 0 for positive numbers and 1 for negative. To obtain a negative number, the 2's complement of the positive number, including the sign bit, is derived. During calculations using 2's-complement working, it is not necessary to keep a check of the sign of partial results. If the answer is negative, as indicated by its sign bit, its 2's complement is taken as the magnitude.

Hence, in 2's-complement arithmetic, subtraction is performed by an addition operation; for example, $(13 - 7)_{10}$ is the same as $\{13 + (-7)\}_{10}$, as illustrated in the following table.

	Sign Bit	
7_{10}	0	0 111
Two's complement of 7_{10}	1	1 001
Add 13_{10}	0	1 101
1	0	0 110

The answer is $+0\,110_2$; i.e., 6_{10}. Note that the most significant bit of the final answer is outside the range of numbers used and is ignored.

(*b*) (*i*) and (*ii*) The one's and 2's complements of the binary numbers 110 101 110 and 111 000 are given in the following table.

Binary Number	One's Complement	Two's Complement
110 101 110	001 010 001	001 010 010
111 000	000 111	001 000

(*c*) $110\,111_2 - 1\,101_2$.

	Sign Bit	
$+ 1\,101_2$	0	001 101
$- 1\,101_2$	1	110 011
Add $110\,111_2$	0	110 111
1	0	101 010

Note that the most significant bit of the final answer is outside the range of numbers being used and is ignored.

Thus, the answer is $+ 101\,010_2$ (i.e., $+42_{10}$).

Q. 3. (*a*) *Draw the truth table for a binary full-adder.*

(*b*) *From the truth table, produce Boolean expressions for the sum and carry, and minimize these expressions.*

(*c*) *Draw a logic diagram of a binary full-adder using* AND, OR, NOT *and* EQUIVALENCE *logic elements.*

A. 3. (*a*) A binary full-adder has inputs and outputs as shown in sketch (*a*), where S represents the sum of inputs A and B, and C_i and C_{i-1} represent the ith and $(i-1)$th carries respectively.

(*a*)

Hence, the truth table for a binary full-adder is as follows.

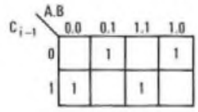
A	B	C_{i-1}	S	C_i
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

(*b*) From the truth table, the Boolean expressions for the sum and carry are

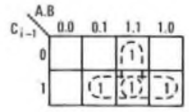
$$S = \bar{A}.\bar{B}.C_{i-1} + \bar{A}.B.\overline{C_{i-1}} + A.\bar{B}.\overline{C_{i-1}} + A.B.C_{i-1},$$

and $C_i = \bar{A}.B.C_{i-1} + A.\bar{B}.C_{i-1} + A.B.\overline{C_{i-1}} + A.B.C_{i-1}.$

The expressions for S and C_i are represented on the Karnaugh maps shown in sketches (*b*) and (*c*) respectively.



(*b*)



(*c*)

From sketch (*b*), it can be seen that the expression for S cannot be minimized further. However, applying the distributive law gives

$$S = (\bar{A}\,.\,\bar{B} + A\,.\,B)\,.\,C_{i-1} + (\bar{A}\,.\,B + A\,.\,\bar{B})\,.\,\overline{C_{i-1}}.$$

The first term of this expression contains an equality in A and B; that is, an output occurs whenever A and B have the same value. Hence, by writing this term as an equality, the logic diagram may be simplified by using an EQUIVALENCE logic element. Thus, the expression becomes

$$S = (A = B)\,.\,C_{i-1} + (\bar{A}\,.\,B + A\,.\,\bar{B})\,.\,\overline{C_{i-1}}.$$

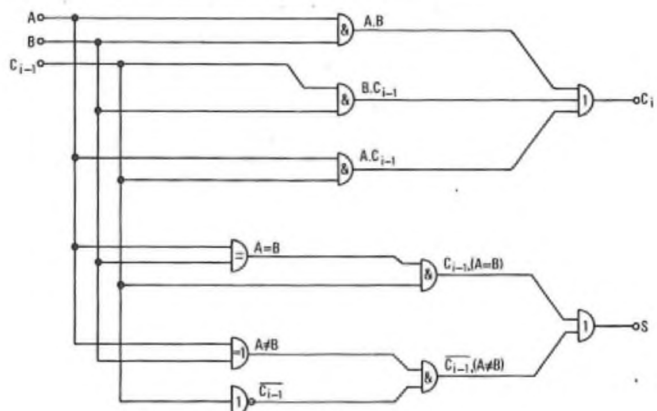
The second term contains an inequality in A and B; that is, an output occurs whenever $A \neq B$. This is commonly referred to as an EXCLUSIVE OR function, and the logic diagram may be further simplified by using an EXCLUSIVE OR logic element. Thus, the expression becomes

$$S = (A = B)\,.\,C_{i-1} + (A \neq B)\,.\,\overline{C_{i-1}}. \quad \ldots\ldots (1)$$

From sketch (*c*), the expression for C_i can be minimized to

$$C_i = A\,.\,B + B\,.\,C_{i-1} + A\,.\,C_{i-1}. \quad \ldots\ldots (2)$$

(*c*) The logic diagram for a binary full-adder, constructed from equations (1) and (2), is shown in sketch (*d*).



(*d*)

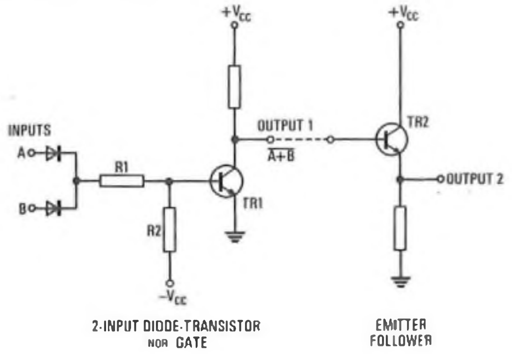
Note: The application of the distributive law to the original expression for C_i gives

$$C_i = (\bar{A}\,.\,B + A\,.\,\bar{B})\,.\,C_{i-1} + A\,.\,B,$$

showing that this expression also contains an EXCLUSIVE OR function. However, the implementation of the expression in this form yields no simplification of the logic diagram, since a total of 4 logic elements would still be required.

Q. 4. With the aid of a circuit diagram, explain the operation of a 2-input diode-transistor NOR *gate for use with a positive-logic convention. Include in your diagram an emitter-follower stage. How does the inclusion of the emitter follower modify the basic* NOR*-gate characteristics?*

A. 4. The sketch shows a 2-input diode-transistor NOR gate with an emitter-follower stage.



Transistor TR1 is normally held in the OFF state by the negative potential applied via resistor R2. If a signal of $+V_{CC}$ volts, defined as *high-level*, is applied either to input A or input B, the corresponding diode is forward biased and, therefore, conducts. The potential divider formed by resistors R1 and R2 is designed to apply a positive potential to the base of transistor TR1, which consequently turns on. Output 1, taken from the collector of transistor TR1, falls from its normal high level of $+V_{CC}$ volts to approximately zero volts, defined as *low-level*. Therefore, if a high-level signal is applied to either input, it is converted to a low-level output. Only when both inputs are simultaneously at a low level is the output at a high level.

If the low level is defined as logic state 0 and the high level as logic state 1 (that is, a positive-logic convention), the operation of the gating circuit is given by the following truth table.

Inputs A	Inputs B	Output 1
0	0	1
0	1	0
1	0	0
1	1	0

The circuit is, therefore, a positive-logic NOR gate.

If output 1 is connected to the base of transistor TR2 in the emitter-follower stage, the signals at output 2 are the same as those at output 1. However, the emitter-follower presents a high input impedance to the NOR gate, but has a low output impedance. It is, therefore, capable of driving a larger number of subsequent gates than the basic NOR gate; that is, the *fan-out* capacity of the circuit is increased.

Q. 5. (a) Draw a block diagram of a simple digital computer, showing the minimum essential registers and their interconnexion. Explain the meaning of each of the blocks.

(b) Using the block diagram, explain the sequence of events in one cycle of the microprogramme.

A. 5. See A.6, Computers B, 1972, *Supplement*, Vol. 66, p. 65, Oct. 1973.

Q. 6. (a) Fig. 1 shows a typical inverter circuit, and Fig. 2 shows the voltage/time waveform of the input voltage, V_i. Redraw Fig. 2 and, on the same time axis, sketch a graph of the output voltage, V_o, and explain the differences between V_i and V_o. (For transistor TR1, $h_{FE} = 20$. The pulse time, T seconds, is long compared with any switching delays in the circuit.)

(b) What would be the effect on the output voltage if resistor R1 were reduced to a significantly lower value?

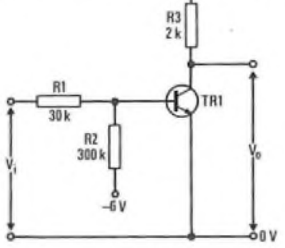


Fig. 1

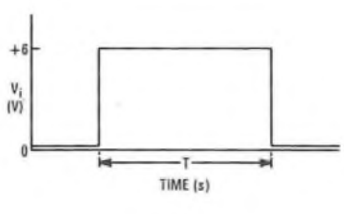
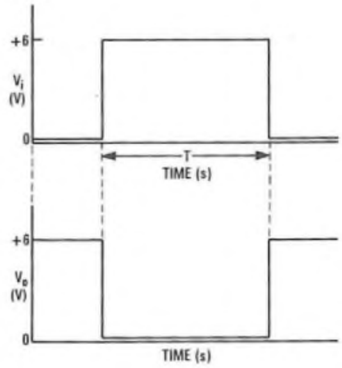


Fig. 2

A. 6. (*a*) The sketch shows the input-voltage waveform, V_i, and the output-voltage waveform, V_o, referred to the same time axis. It can be seen that V_o is the inversion of V_i. The waveform for V_o is derived as described below.



When $V_i = 0$ V, the base voltage, V_{BE}, of transistor TR1 is given by

$$V_{BE} = \frac{R_1}{R_1 + R_2} \times (-6)\ \text{V}, \qquad \ldots\ldots (1)$$

$$= \frac{30 \times 10^3}{30 \times 10^3 + 300 \times 10^3} \times (-6) = -0{\cdot}55\ \text{V}.$$

This voltage is sufficient to maintain transistor TR1 in the OFF state. Hence, no current flows through resistor R3, and V_o is maintained at the supply potential; that is, $V_o = +6$ V.

When $V_i = +6$ V, a base current, I_B, flows. Neglecting the base-emitter potential, I_B is given by

$$I_B = \frac{V_i}{R_1} + \frac{(-6)}{R_2}\ \text{A}, \qquad \ldots\ldots (2)$$

$$= \frac{6}{30 \times 10^3} + \frac{(-6)}{300 \times 10^3}\ \text{A} = 0{\cdot}18\ \text{mA}.$$

Now, the minimum base current, $I_{B(MIN)}$, required to switch on transistor TR1 is derived from the normal collector current, I_C, flowing when transistor TR1 is in the ON state. Neglecting the collector-emitter potential, I_C is given by

$$I_C = \frac{6}{R_3}\ \text{A},$$

$$= \frac{6}{2 \times 10^3}\ \text{A} = 3\ \text{mA},$$

and $I_{B(MIN)}$ is given by

$$I_{B(MIN)} = \frac{I_C}{h_{FE}}\ \text{A},$$

$$= \frac{3 \times 10^{-3}}{20}\ \text{A} = 0{\cdot}15\ \text{mA}.$$

Therefore, when $V_i = +6$ V, the base current is in excess of the minimum required, and transistor TR1 is switched on. Hence, V_o is at zero potential.

(*b*) If resistor R1 were reduced, then, from equation (2), I_B would be increased. Hence, transistor TR1 would be more saturated in its ON state. Also, from equation (1), the negative bias voltage available to maintain transistor TR1 in its OFF state would be significantly reduced.

Q. 7. (a) What is meant by the term subroutine?

(b) Consider the formula $Z = \sqrt{(R^2 + X^2)}$.

Write a programme to calculate Z where a square-root subroutine is already in the store to be entered at location 128. The subroutine takes the initial value from location 64 and leaves the result in the accumulator, after which it refers to location 1 for the link address. Give a key to any code used.

Q. 8. (a) With the aid of a sketch of a hysteresis loop of a typical ferrite core, explain in detail the effects on the hysteresis loop of

(i) full currents, and

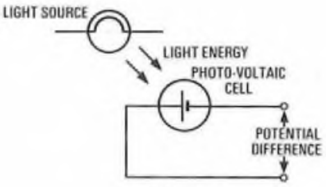
(ii) successive half-currents.

The additive effects of half-current pulses in a large coincident-current store could cause spurious outputs. Name 3 methods that may be used to suppress or overcome the effect of these outputs, and discuss 2 of them in detail.

Q. 9. *(a) With the aid of sketches, explain what is meant by the term transducer.*

(b) Describe 2 digital methods of measuring the speed of rotation of a shaft. Discuss the advantages and disadvantages of each method.

A. 9. (*a*) A transducer is a device which converts energy from one form to another. A photo-voltaic cell, illustrated in sketch (*a*), is an example of a transducer, since it converts an intensity of illumination into a potential difference; that is, light energy is converted into electrical energy. Microphones and loudspeakers are also examples of transducers.



(*a*)

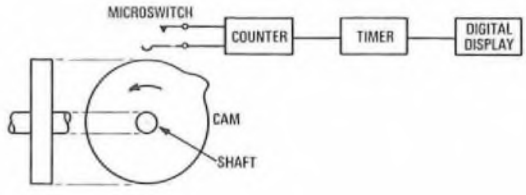
(*b*) Two digital methods of measuring the speed of rotation of a shaft are described below.

(*i*) Sketch (*b*) shows a cam, fixed to a rotating shaft, and arranged to operate a microswitch once during each revolution. The duration between output pulses from the microswitch is inversely proportional to the angular velocity of the shaft. The pulses are counted and timed over a given period, and the result is displayed in terms of revolutions/minute, using appropriate electronic circuitry.

The disadvantages of this system are that

(1) a special cam must be manufactured,

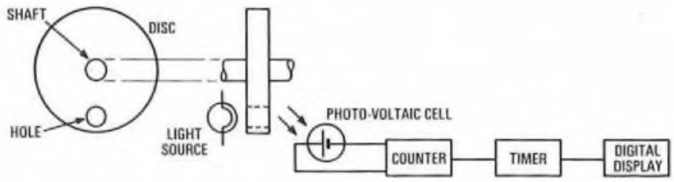
(2) it has moving parts (i.e., a mechanical contact unit) which can be unreliable, and



(*b*)

(3) it will not work at very high speeds because of the mechanical limitations of the microswitch.

(*ii*) Sketch (*c*) shows an arrangement whereby a photo-voltaic cell senses light through a hole in a disc attached to the shaft when the hole aligns with a light source. Again, the time between successive pulses is measured, giving the speed of rotation as described above. Because of the high operating speed of the photo-voltaic cell, it is practical to have a large number of holes around the circumference of the disc, and the speed of rotation can, therefore, be calculated in a shorter period.



(*c*)

The advantages of this system are that

(1) there are no moving parts and, therefore, no wear, and

(2) the operating speed is higher than for mechanical devices.

A disadvantage is that any other incident light may interfere with its operation.

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