# SUPPLEMENT

## TO THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

**Vol. 69 Part 2 July 1976**

## CITY AND GUILDS OF LONDON INSTITUTE EXAMINATIONS 1975

## Contents

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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 published in 32-page and 16-page sizes.**

## TELEPHONY AND TELEGRAPHY A, 1975

**Students were expected to answer any 6 questions**

*Q 1* (*a*) *Why is it desirable to reduce the level of sidetone in a subscriber's telephone*

(*i*) *when speaking, and*
(*ii*) *when listening?*

(*b*) *With the aid of sketches, explain how sidetone is reduced.*

(*c*) *Why is the total suppression of sidetone*

(*i*) *not desirable, and*
(*ii*) *not practicable?*

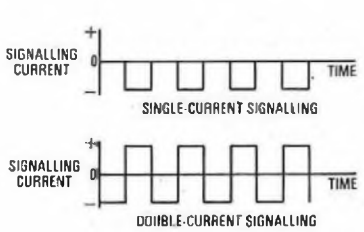
A 1 See A1, Telephony and Telegraphy A, 1974, *Supplement*, Vol. 68, p. 18, Apr. 1975.

*Q 2* (*a*) *Distinguish between the single-current and double-current methods of line signalling.*

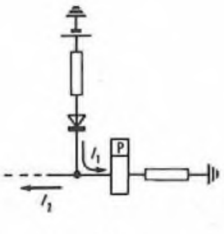
(*b*) *Give 3 reasons why a polarized relay is normally chosen for receiving double-current line signals.*

(*c*) *Explain how a polarized relay can be electrically biased for receiving single-current line signals.*

A 2 (*a*) Line signals are normally binary in character, consisting of combinations of 2 separate conditions; for example, *make* and *break* or *mark* and *space* signals. The 2 conditions can be represented either by 2 distinct signals, as in double-current signalling, or by a signal and the absence of a signal, as in single-current signalling. Sketch (*a*) shows a train of 8 signalling elements of alternate condition, represented in single-current form by 4 current pulses interspersed with 4 periods of no current, and in double-current form by alternate positive and negative current pulses.



(*a*)



(*b*)

(*b*) Double-current working requires a receiving device capable of responding differently to the 2 directions of line current. A conventional relay is not sensitive to current direction; it operates to currents in either direction. Special biasing arrangements are therefore required to make a conventional relay operate to current in one direction but release when an equal current is received in the opposite direction. Such biasing is possible, but not often satisfactory because the OPERATE and RELEASE characteristics of relays are different and pulse distortion is introduced. A polarized relay requires no such bias; it has 2 stable conditions, one in each sense, and these have symmetrical characteristics.

Another reason for using polarized relays is their speed of operation One of the advantages of double-current working is an improvement in the transmission rate by hastening the discharge of the line capacitance when the signal state changes. Thus, a high-speed relay is desirable, and the standard polarized (Carpenter) relay is very fast in its operation.

A requirement of fast transmission is that light currents be used. The good sensitivity of a polarized relay is therefore an asset, since the relay operates satisfactorily to a current of less than 1 mA.

(*c*) Sketch (*b*) illustrates a method of electrically biasing a polarized relay for receiving single-current signals. A constant biasing current, $I_1$, flows from the positive battery, via the resistor and diode, to operate the relay to its SPACE sense when no line current is flowing. The value of $I_1$ is arranged so that, when a signal current, $I_2$, (which is negative) is received, the algebraic sum of the currents is a current in the direction of $I_2$ large enough to operate the relay to its MARK sense.

*Q 3* *Some important properties of materials are their electrical conductivity, magnetic permeability, and mechanical hardness.*

(*a*) *State, with reasons, whether the above properties are desirable or undesirable for the following parts of a relay:*

(*i*) *the armature,*
(*ii*) *the wire used in the coil, and*
(*iii*) *the residual screw or stud.*

(*b*) *For each of the relay parts in* (*a*), *state which of the following materials would best provide the desirable properties: brass, aluminium, lead, soft iron, copper, and hard steel.*

A 3 (*a*) (*i*) A relay armature requires a material with a high magnetic permeability so that a high magnetic flux density is achieved for a given magnetizing force. A reasonable degree of mechanical hardness is necessary to reduce wear at the pivot, but high electrical conductivity is undesirable since this increases eddy-current losses.

(*ii*) Coil-winding wire requires a high electrical conductivity so that a large number of turns can be wound without the resistance exceeding a reasonable limit. The force exerted on the armature by an energized coil depends on the number of turns and the current flowing. Thus, for a large force, both a large number of turns and a high current are desirable. A high conductivity permits these characteristics to be obtained without recourse to high energizing voltages, and also minimizes the energy losses (as heat) caused by the coil's resistance.

(*iii*) The residual screw or stud requires 2 characteristics: mechanical hardness and a very low magnetic permeability. Low permeability is the principal requirement, so that a high-reluctance gap is maintained in the magnetic circuit. This ensures that the magnetic flux decays rapidly when the coil ceases to be energized and, so, allows rapid release of the relay. Mechanical hardness is necessary to withstand the hammering action of relay operation and to ensure that the residual gap is not unacceptably reduced by flattening of the stud or screw.

(*b*) (*i*) Soft iron is the most suitable material for the armature since it has high permeability, low remanence and adequate mechanical strength and hardness. Of the materials listed, only hard steel has a permeability approaching that of soft iron, but is unsuitable because of its high remanence. (*Hard* and *soft*, in this context, refer to the remanence rather than mechanical hardness; hard materials are highly remanent while soft materials are very much less so.) The other materials listed are not ferro-magnetic, and all have very low permeabilities.

(*ii*) The most suitable material for the winding is copper since it has the highest conductivity. It is also highly ductile, and is therefore easily drawn into the fine wire required. Aluminium or brass are the best alternatives, but are considerably less desirable than copper. All the other materials are conductors, and it would therefore be possible to construct coils from them, but their electrical and mechanical properties are far from ideal.

(*iii*) The most suitable material for the residual screw or stud is brass since it has low permeability and adequate mechanical hardness. Copper, aluminium and lead also have low permeabilities, but are mechanically soft and could not stand up to repeated hammering against the pole face. Soft iron and hard steel have sufficient mechanical hardness, but are unacceptable because of their high permeabilities. Some special non-magnetic steels may be suitable, but would probably be more expensive than brass.

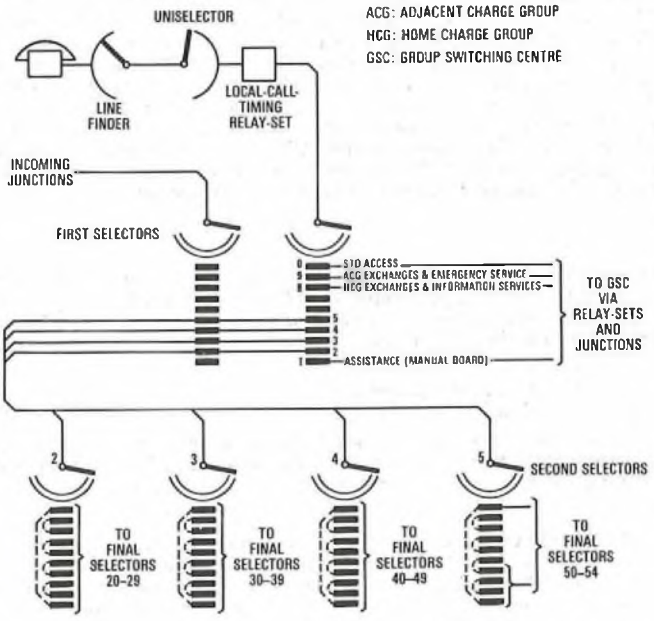
*Q 4* (*a*) *Draw a simple trunking diagram of a step-by-step exchange catering for 3500 subscribers' lines, using line finders for connecting them to first selectors.*

(*b*) *At any switching stage, what determines which selector in that stage will be used by the next caller?*

(*c*) *Under what conditions, and from which selectors, might a caller hear*

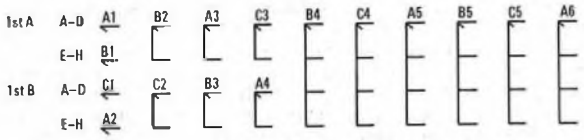
(*i*) *engaged tone,*
(*ii*) *ring tone, and*
(*iii*) *number-unobtainable tone?*

A 4 (*a*) Sketch (*a*) shows the trunking diagram for a 3500-line exchange using line finders.



(*a*)

(*b*) At any switching stage, the selector used by a caller is determined by the selectors that are in use at that time and by the order in which the selectors are tested by the previous selector.



(*b*)

Considering a group of, say, 16 second selectors arranged over 3 shelves, A1–6, B1–5 and C1–5, a typical connexion pattern would be as shown in sketch (*b*). For calls originating from shelves A–D of first-selector rack A, the testing sequence is

A1, B2, A3, C3, B4, C4, A5, B5, C5, A6,

and, for calls originating from shelves E–H of that rack, the testing sequence is

B1, B2, A3, C3, B4, C4, A5, B5, C5, A6.

For each of the 4 grading groups, the second selector seized is the first free one encountered in the testing sequence during rotary hunting of the first selector.

(*c*) (*i*) Engaged tone is applied by a final selector when an engaged-subscriber's line is tested. (Equipment-engaged tone is applied by a group selector that does not encounter a free outlet during rotary hunting.)

(*ii*) Ring tone is returned from a final selector when ringing current is being applied to a free-subscriber's line.

(*iii*) Number-unobtainable tone can be applied by a final selector when an unallocated number is dialled, or by a group selector when a spare level is dialled.

*Q 5* (*a*) *List the principal functions of a cord circuit on a switchboard at a local manual exchange.*

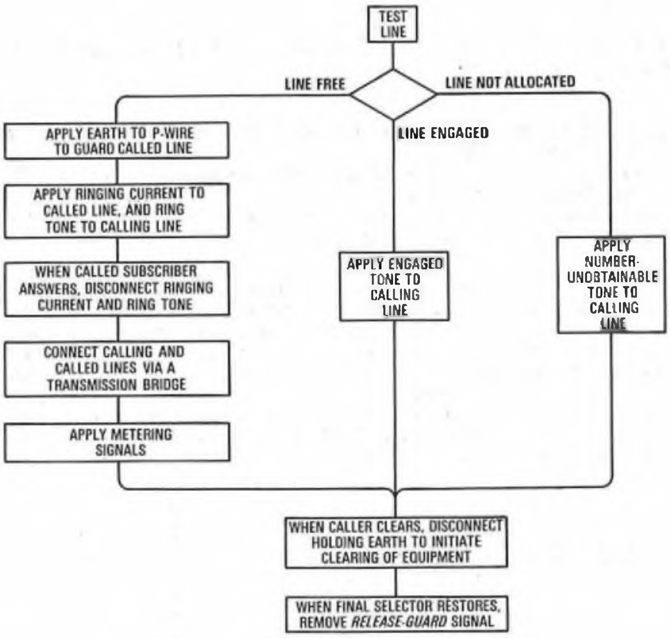
(*b*) *List the functions performed by a final selector after it has stepped to the required line.*

(*c*) *Explain why traffic intensity determines the number of cord circuits, or final selectors, required to serve a given number of lines.*

A 5 (*a*) The principal functions of a cord circuit on a switchboard at a local manual exchange are to provide

(*i*) a means of testing whether a line is free or engaged,
(*ii*) a signal to indicate to other operators that a line connected to the cord circuit is engaged,
(*iii*) ringing current,
(*iv*) supervisory facilities,
(*v*) a transmission bridge, and
(*vi*) metering facilities.

(*b*) The functions of a final selector, after it has stepped to a selected line, are shown in the sketch.



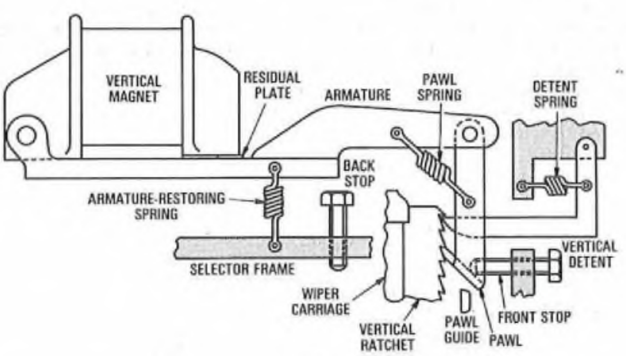
(*c*) The factor that determines the number of cord circuits or final selectors in a group is the expected (or average) number of simultaneous calls. Over any observed period, the average number of simultaneous calls is equal to the traffic intensity in erlangs. Hence, the number of cord circuits or final selectors provided is determined by the traffic intensity. It is usual to make provision for handling more than the average number of simultaneous calls, but less than the highest number of simultaneous calls that can be expected. Thus, a proportion of the calls attempted fails because of congestion; this proportion is known as the *grade of service*, and is specified in the design of an exchange.

*Q 6* (*a*) *With the aid of a sketch, describe the mechanical action of a 2-motion selector during either vertical or horizontal stepping.*

(*b*) *Why should excessive armature travel in the stepping magnets be avoided?*

(*c*) *Briefly explain why a shortened magnet-energizing pulse can cause the selector to overstep.*

A 6 (*a*) Sketch (*a*) shows the vertical-stepping mechanism for a 2-motion selector, with the magnet operated.

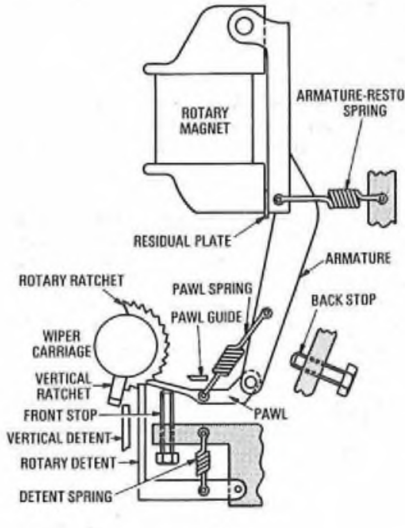


(*a*)

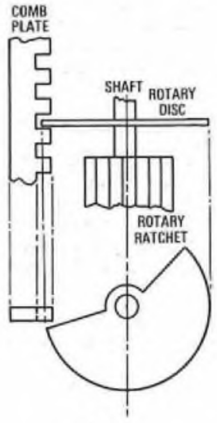
When in the normal position, the armature is held firmly against the back stop by the armature-restoring spring. When the magnet is energized, the armature is attracted, and the pawl, under the influence of the pawl spring, is directed by the pawl guide into the root of a vertical-ratchet notch, thus lifting the wiper carriage. The vertical detent slides over the first tooth of the vertical ratchet and, just as it engages the next notch, the pawl is wedged between the front stop and the vertical ratchet, so arresting the vertical movement of the carriage.

When current ceases to flow in the magnet coil, the armature restores under the combined forces of gravity and the tension in the armature-restoring spring. The vertical detent, in engagement with a notch in the vertical ratchet, holds the wiper carriage in the raised position.

Sketch (*b*) shows the rotary-stepping mechanism for a 2-motion selector, with the rotary magnet operated.



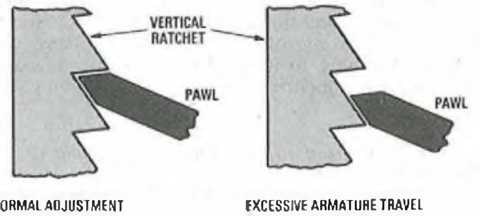
(*b*)



(*c*)

When in the normal position, the armature is held firmly on the back stop by the armature-restoring spring. When the magnet is energized, the armature is attracted, and the pawl, under the influence of the pawl spring, is directed by the pawl guide into the root of a rotary-ratchet notch, thus rotating the wiper carriage. The rotary detent slides over the first tooth of the rotary ratchet at the same time as the pawl strikes the front stop. During the first rotary step, the vertical ratchet leaves the vertical detent but, at the same time, the rotary disc fitted on the wiper carriage enters the appropriate notch in the comb plate, as shown in sketch (*c*), which supports the carriage during rotary stepping. When current ceases to flow in the magnet coil, the rotary detent, engaged in a notch in the rotary ratchet, holds the carriage against the tension of the rotary-restoring spring (not shown). The armature returns to the normal position under the tension of the armature-restoring spring.

(*b*) Excessive armature travel is caused by maladjustment of the back stop, allowing the armature to restore to a position further from the pole face than is desirable. This results in the pawl resting not in the root of a tooth but some distance along the long face of the next tooth. Sketch (*d*) shows a vertical pawl and ratchet in normal adjustment and with excessive armature travel, with the magnet released.



(*d*)

When the armature operates, the pawl accelerates towards the short face of the ratchet tooth. If the travel is excessive, the speed attained by the pawl is high. This leads to a violent impact with the short face and consequent rapid wear of the ratchet and pawl.

(*c*) In normal operation, the motion of the wiper carriage is arrested at the end of a stroke by the wedging of the pawl between the ratchet and the front stop. This stops the carriage positively and prevents its momentum carrying it an additional step.

If the magnet is energized by a shortened pulse, the wiper carriage is accelerated, but the armature starts to restore before the pawl wedges with the front stop. Consequently, the wiper carriage is free to continue under its own momentum. Under unfavourable circumstances, this can result in the carriage moving 2 steps.

*Q 7* (*a*) *With the aid of sketches, describe the operation of*

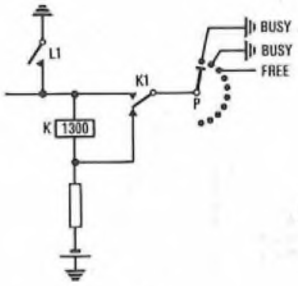
(*i*) *an earth-testing circuit element, and*
(*ii*) *a battery-testing circuit element.*

(*b*) *What advantages are offered by the battery-testing method during*

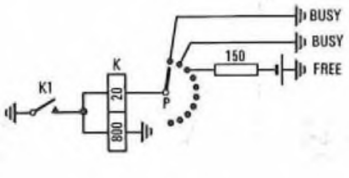
(*i*) *setting-up a call, and*
(*ii*) *clearing a call?*

A 7 (*a*) (*i*) A basic earth-testing circuit element is shown in sketch (*a*). Relay L (not shown) is initially operated, and contact L1 extends earth to one side of relay K, the other side of which is connected to battery. When the selector is standing on a busy outlet, relay K is effectively short-circuited by the busying earth from the P-wiper via contact K1, and does not operate. When the selector is standing on a free outlet, no earth is present on the P-wiper, and relay K operates to the earth at contact L1. Contact K1 extends the K relay to the P-wiper; other contacts of relay K extend the line wires and disconnect relay L, which is slow to release. The release lag of relay L is sufficient to maintain a holding circuit for relay K, to the earth at contact L1, until a holding earth is returned on the P-wiper from the next switching stage.

A bridging P-wiper is used to prevent the false operation of relay K to the momentary disconnexion that would otherwise occur as a normal wiper moves between contacts.



(*a*)



(*b*)

(*ii*) A basic battery-testing circuit element, of the *marginal-hold* type, is shown in sketch (*b*). Relay K is extended, with its high-resistance and low-resistance coils in series, to the P-wiper. Busy outlets are marked by an earth (or, in some circuits, by a disconnexion) and relay K cannot operate. A free outlet is marked by a 150 Ω battery, to which relay K operates. Contact K1 short-circuits the high-resistance coil, thus reducing the P-wiper potential to about 6 V and preventing any other testing relays K from switching to the outlet. (The outlet is subsequently guarded by an earth condition when switching is completed.)

The 150 Ω battery provides sufficient current to operate 2 relays K in parallel if simultaneous switching occurs. However it does not provide sufficient current to hold both relays over their low-resistance coils. Thus, if double switching occurs, both relays K operate but fail to hold, and both selectors continue hunting.

(*b*) (*i*) During the setting-up of a call, battery-testing circuits give immunity from double switching. They also give freedom from false switching due to fault conditions that result in a disconnected P-wire.

(*ii*) During the clearing of a call, battery-testing circuits give immunity from switching to an outlet during the unguarded P-wire interval in the release sequence of the preceding call on that outlet.

*Q 8* (*a*) *Draw a diagram to illustrate the principle of the common control of crossbar switches.*

(*b*) *What information is fed by the caller to the common-control equipment, and by which path?*

(*c*) *Outline the principal functions of the common-control equipment in controlling the establishment of the required connexion.*

(*d*) *What influences the number of common-control equipments provided?*

*Q 9* *The table shows the traffic offered to each of the trunks in a full-availability group of 8 trunks.*

| *Trunk No.* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|
| *Traffic Offered (erlangs)* | *4* | *3·20* | *2·40* | *1·75* | *1·20* | *0·75* | *0·47* | *0·25* |

(*a*) *How much traffic is carried by each of trunks 1–7 inclusive?*

(*b*) *How could you use the information given to find the traffic carried by the eighth trunk?*

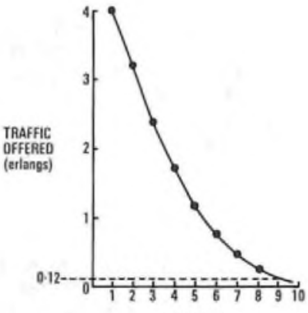
(*c*) *What is the grade of service given when the following trunks are artificially busied against traffic:*

(*i*) *trunk 8,*
(*ii*) *trunks 7 and 8, and*
(*iii*) *trunks 2, 7 and 8?*

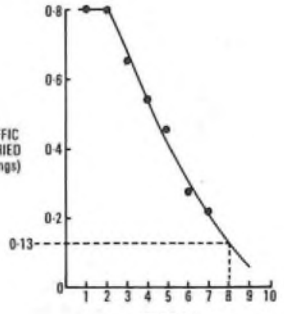
**A 9** (*a*) The traffic carried by any trunk is given by the traffic offered to that trunk minus the traffic offered to the subsequent trunk. The traffic carried by trunks 1–7 is given in the table.

| Trunk No. | Traffic Offered (erlangs) | Traffic Carried (erlangs) |
|---|---|---|
| 1 | 4 | 4 − 3·2 = 0·8 |
| 2 | 3·2 | 3·2 − 2·4 = 0·8 |
| 3 | 2·4 | 2·4 − 1·75 = 0·65 |
| 4 | 1·75 | 1·75 − 1·2 = 0·55 |
| 5 | 1·2 | 1·2 − 0·75 = 0·45 |
| 6 | 0·75 | 0·75 − 0·47 = 0·28 |
| 7 | 0·47 | 0·47 − 0·25 = 0·22 |
| 8 | 0·25 | — |

(*b*) The traffic carried by trunk 8 can be found by graphical use of the information given.



(*a*)



(*b*)

Sketch (*a*) shows a graph of the traffic offered to each trunk plotted against the trunk number. By extrapolation, the traffic offered to trunk 9 is 0·12 erlang.

Therefore, the traffic carried by trunk 8

$$= 0\cdot25 - 0\cdot12 = 0\cdot13 \text{ erlang.}$$

Alternatively, sketch (*b*) shows a graph of traffic carried against trunk number. By extrapolation, the traffic carried by trunk 8 is 0·13 erlang.

A further method is to evaluate the grade of service for the whole group using an expression known as *Erlang's formula*, which relates the grade of service, the traffic and the number of trunks. The traffic lost can be derived from the grade of service. Hence, the traffic carried by trunk 8 is given by the traffic offered to trunk 8 minus the traffic lost for the group. (Erlang's formula is outside the scope of the syllabus.)

(*c*) (*i*) The grade of service, *B*, is given by the traffic lost divided by the traffic offered. With trunk 8 busied, the traffic lost is the traffic offered to trunk 8.

$$\therefore\ B = \frac{\text{traffic offered to trunk 8}}{\text{traffic offered to the group}},$$

$$= \frac{0\cdot25}{4} = 0\cdot0625,$$

or one call lost for 16 offered.

(*ii*) With trunks 7 and 8 busied,

$$B = \frac{\text{traffic offered to trunks 7 and 8}}{\text{traffic offered to the group}},$$

$$= \frac{0\cdot47}{4} = 0\cdot1175,$$

or 2 calls lost for approximately 17 offered.

(*iii*) With trunks 2, 7 and 8 busied, the traffic originally offered to trunk 2 is now offered to trunk 3, and so on. This is equivalent to trunks 6, 7 and 8 being busied.

$$\therefore\ B = \frac{\text{traffic offered to trunks 6, 7 and 8}}{\text{traffic offered to the group}},$$

$$= \frac{0\cdot75}{4} = 0\cdot1875,$$

or 3 calls lost for 16 offered.

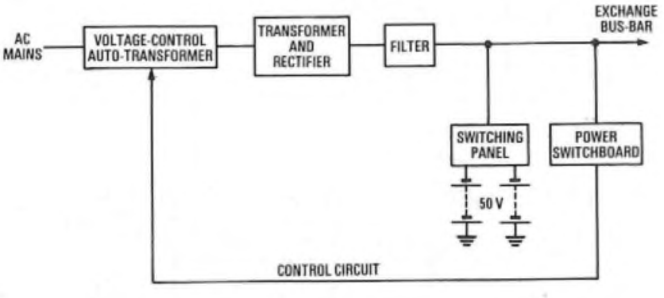
*Q 10* (*a*) *Explain why the following are included in some telecommunications power plants but not in others:*

(*i*) *a smoothing device, and*
(*ii*) *a voltage-control device.*

(*b*) *Draw a block diagram of a power plant suitable for a 50 V exchange using both smoothing and voltage-control devices.*

(*c*) *Outline the principle of operation of a voltage-control arrangement appropriate to the block diagram.*

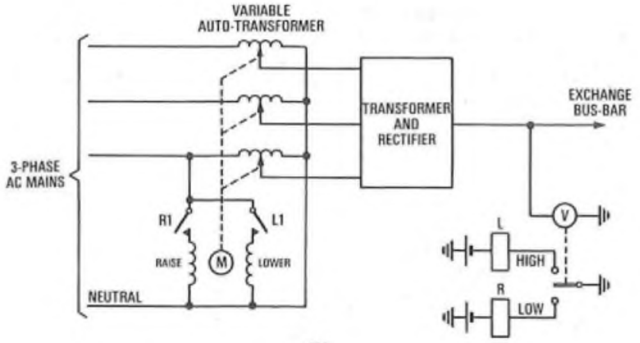
**A 10** (*a*) (*i*) Smoothing devices are necessary in partial charge-discharge and float-type power plants because the outputs from rectifiers and d.c. generators contain an alternating, or ripple, component. If the ripple reaches the exchange bus bars, it is heard as background noise to all conversations in the form of a hum (for rectifier systems) or whistle (for generator systems). A low-pass filter is therefore provided which readily passes d.c. but offers a high impedance to the ripple.



(*a*)

Charge-discharge systems do not require a filter since the battery connected to the exchange at any time is isolated from the charging circuit, and a moderate ripple has little effect on the battery being charged.

(*ii*) Similarly, voltage-control devices are required in partial charge-discharge and float-type systems but not in charge-discharge systems. This is partly due to charge-discharge systems being used only in older types of exchange, in which voltage fluctuations are less critical, and to the basic system design being such that the voltage can only decrease (as the exchange battery discharges). In the latter case, the only possible remedy is to change over to the alternative battery, and this is a manual operation. On more modern systems, batteries are



(*b*)

floated, that is, charged while connected to the exchange load, and thus the terminal voltage can rise or fall. Hence, voltage control is necessary, and can be provided by counter-e.m.f. cells, end-cell switching, or control of the alternating voltage on the mains side of the rectifier.

(*b*) Sketch (*a*) shows a block diagram of a 50 V exchange power plant using smoothing and voltage-control devices.

(*c*) Sketch (*b*) illustrates the variable auto-transformer type of voltage-control device. The rectifier is fed via a variable auto-transformer. Control circuitry is arranged to monitor the exchange bus-bar voltage and operate relay L if the voltage is too high, or relay R if too low. Contact L1 completes a circuit for the LOWER winding of the regulating motor, which mechanically drives the variable taps to reduce the voltage supplied to the rectifier. Similarly, contact R1 energizes the RAISE winding, and the taps are driven in the opposite direction to raise the voltage. Safeguards are built into the control circuitry to prevent rapid hunting between the 2 conditions.

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## RADIO AND LINE TRANSMISSION B, 1975

**Students were expected to answer any 6 questions**

*Q 1* (*a*) *Draw the circuit diagram of a 2-stage transistor amplifier suitable for use in the intermediate-frequency stages of a communications receiver.*

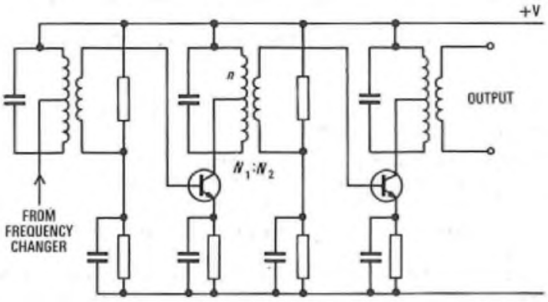
(*b*) *State, with reasons, the preferred configuration of the transistors.*

(*c*) *What is the approximate output resistance of the first transistor?*

(*d*) *The capacitance in the resonant circuit is 100 pF, the intermediate frequency is 465 kHz, and the bandwidth at the −3 dB points is 10 kHz. Calculate the dynamic impedance of the circuit.*

(*e*) *Explain how the circuit in part* (*d*) *is connected to the output of the transistor in part* (*c*).

A 1 (*a*) The circuit diagram of a 2-stage transistor amplifier, suitable for use in the intermediate-frequency stages of a communications receiver, is shown in the sketch.



(*b*) The common-emitter configuration is preferred since this gives the highest voltage and current gains. Also, the input and output impedances are similar, which simplifies matching, and the thermal and frequency stabilities are good.

(*c*) The output impedance of a transistor in the common-emitter configuration is typically 10–20 kΩ.

(*d*) The $Q$-factor of a resonant circuit is given by

$$Q = \frac{f_0}{B},$$

where $f_0$ is the resonant frequency (hertz), and $B$ is the bandwidth at the −3 dB (or half-power) points (hertz).

$$\therefore\ Q = \frac{465 \times 10^3}{10 \times 10^3} = 46{\cdot}5.$$

The dynamic impedance of the circuit at resonance, $Z_D$, is given by $Q$ multiplied by the reactance of one arm of the parallel circuit.

$$\therefore\ Z_D = \frac{Q}{\omega_0 C}\ \text{ohms},$$

where $C$ is the capacitance (farads), and $\omega_0 = 2\pi f_0$ radians/second.

$$\therefore\ Z_D = \frac{46{\cdot}5}{2\pi \times 465 \times 10^3 \times 100 \times 10^{-12}}\ \Omega,$$

$$= \underline{159\ \text{k}\Omega.}$$

(*e*) The resonant circuit is connected into the collector circuit using a tapped-primary-winding transformer, as shown in the sketch. This provides matching between the transistor's output impedance, $Z_{out}$, and the dynamic impedance of the resonant circuit. If $N_1$ is the number of turns on the primary winding and $n$ the number of turns tapped by the collector of the first transistor, then, by auto-transformer action,

$$\frac{N_1}{n} = \sqrt{\frac{Z_D}{Z_{out}}} = \sqrt{\frac{159 \times 10^3}{10 \times 10^3}} \approx 4:1,$$

assuming $Z_{out} = 10$ kΩ.

*Q 2* (*a*) *With the aid of waveform sketches and circuit diagrams, describe the operation of a diode detector suitable for amplitude-modulated signals.*

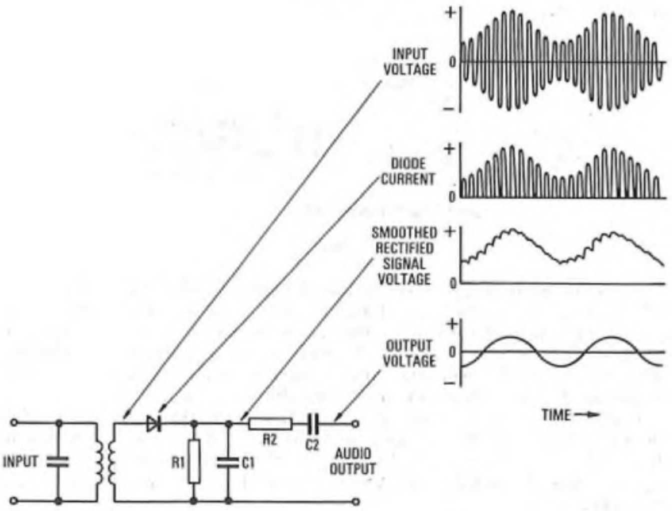
(*b*) *What factors determine the values of the load resistor and shunt capacitor?*

(*c*) *Give component values suitable for a detector operating at a carrier frequency of 465 kHz with modulating frequencies of up to 10 kHz.*

(*d*) *Explain why the detector described may not be suitable for low-level signals.*

(*e*) *State an advantage of using a semiconductor over a thermionic diode.*

A 2 (*a*) The circuit diagram of a diode detector, together with the waveforms appearing at different parts of the circuit, is shown in the sketch.



The input signal, a double-sideband amplitude-modulated intermediate-frequency (IF) carrier, is applied to the diode. The diode conducts only for positive half-cycles of the input waveform, producing current pulses which charge capacitor C1 to the peak value of each half-cycle. Charging occurs rapidly because the time constant of capacitor C1 and the forward resistance of the diode is small. When the input signal is negative, the diode does not conduct, and capacitor C1 discharges through resistor R1 with a much longer time constant. Thus, the signal is rectified and smoothed to give the required audio signal superimposed on a direct voltage virtually equal to the amplitude of the unmodulated carrier. A ripple voltage at the carrier frequency is also present.

Resistor R2, in conjunction with the input capacitance of the following stage, filters out the ripple voltage, and capacitor C2 blocks the direct component, leaving the required audio signal as the output voltage.

(*b*) The factors affecting the choice of values for resistor R1 and capacitor C1 are listed below.

(*i*) The time constant, $C_1R_1$ seconds, must be long compared with the carrier-frequency period, so that the amplitude of the ripple voltage is minimal, but short compared with the audio-frequency period, so that the waveform of the latter is accurately followed.

(*ii*) The value of resistor R1 must be large compared with the forward resistance of the diode to minimize the potential-dividing effect on the signal.

(*iii*) The values of both components should be ones in which they are readily available; that is, "preferred" values.

(*c*) The period of the IF is $1/(465 \times 10^3)\,\text{s} = 2{\cdot}15\,\mu\text{s}$, and that of the highest audio frequency is 100 μs. A suitable value for the time constant is therefore about 15 μs.

If $R_1$ is chosen to be 10 kΩ, which will not load the IF transformer and is a preferred value, $C_1$ is given by $(15 \times 10^{-6})/(10 \times 10^3) = 1{\cdot}5\,\text{nF}$.

(*d*) The detector is not suitable for the detection of low-level signals because the voltage/current characteristic of the diode is non-linear at low voltages, up to about 0·8 V. If the detector were used at this level, the resulting signal would be distorted.

(*e*) The advantages of a semiconductor diode over a thermionic diode are its small size, its lower self-capacitance, its greater reliability, and the fact that it requires no heater and gives a lower voltage drop.

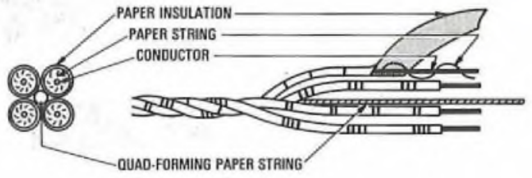
*Q 3* (*a*) *Describe in detail, with the aid of sketches, 2 of the following types of cable:*

(*i*) *24-pair carrier-type quad cable,*
(*ii*) *balanced-and-screened-pair cable, and*
(*iii*) *multipair coaxial cable.*

(*b*) *State the uses and the frequency range of each type described.*

A 3 (*a*) (*i*) Twenty-four-pair carrier-type quad cable is made up of 12 quads in a single sheath. A quad is shown in sketch (*a*), and consists of 4 copper conductors, 1·27 mm in diameter, each lapped with a paper string and covered by a paper wrapping. The 4 insulated conductors are twisted together around a paper string to form the quad.

Individual conductors of a quad are identified by groups of from 1–4 coloured markings on the paper insulation. The spacing of the markings varies for each wire of the quad so that the amount of ink on the insulating paper of each conductor is the same. This limits the amount of capacitive imbalance produced by the markings. The characteristic impedance of each pair is about 140 Ω in the working frequency range.



(*a*)

The cable is made up of 3 central and 9 outer quads, giving a diameter of about 25 mm. These are lapped with 2 thicknesses of insulating paper, the outer one being coloured to identify the type of material used for the sheath. The sheath is either lead or a lead alloy, and may be overlaid with steel-tape armouring for extra protection when required. The overall diameter of the cable is 29 mm.

Care is taken in the construction of the cable to achieve a uniform characteristic impedance and minimum crosstalk between circuits in the cable. For the latter, the twist-length of the different quads making up the cable is varied to reduce the mutual interference as much as possible.

The attenuation of this type of cable varies from 0·62 dB/km at 12 kHz to 2·18 dB/km at 100 kHz.

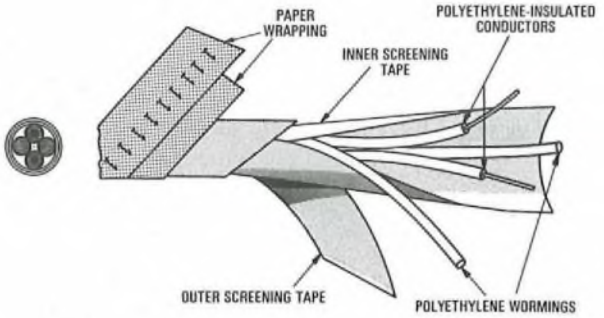
(*ii*) A balanced-pair cable consists of 1·27 mm diameter conductors insulated with 1·4 mm thick extruded cellular polyethylene. The insulation consists of non-interconnecting cells and has a smooth external finish. This type of cable is also known as *screened video cable*.

Two insulated conductors, forming a balanced pair, and 2 wormings of the same material as the insulant, are uniformly twisted together to provide a core that is almost circular in cross-section. The core is then whipped with glass-fibre yarn to preserve its formation.

The pair is screened by an overlapped copper screening tape applied along its length and folded around it. A further copper screening tape is then applied helically around the pair.

Finally, 2 or more thicknesses of insulating paper are applied over the copper screens, the outermost bearing the numerical identification of the pair in black ink.

The overall diameter of a complete pair is about 9·2 mm. The construction of a pair is illustrated in sketch (*b*) (glass-fibre yarn not shown).



(*b*)

Pairs are made up into variously sized cables, usually with a number of interstitial or layered audio pairs or quads. The sheath is polyethylene with an aluminium-foil moisture barrier.

The attenuation of this type of cable varies from 0·39 dB/km at 1 kHz to 10·2 dB/km at 4 MHz.

(*iii*) See A3, Radio and Line Transmission B, 1974, *Supplement*, Vol. 68, p. 50, Oct. 1975.

(*b*) The 24-pair carrier-type quad cable is used over the frequency range 12–108 kHz, carrying 24 channels on each pair.

Balanced-and-screened-pair cables are used when it is necessary to transmit frequencies higher than 250 kHz and, since the screening effect is not dependent upon frequency, can be used for d.c. signals. They are therefore commonly used for video signals in the 0–4 MHz frequency range.

Multipair coaxial cables are used for long-distance multichannel telephony. Typical frequency ranges are 60 kHz–4 MHz, or 300 kHz–12 MHz, the latter carrying 2700 telephony channels on each pair.

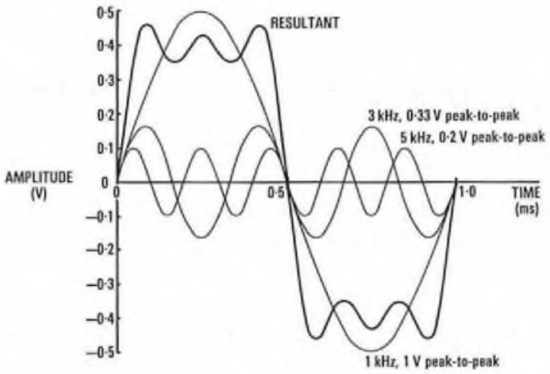
*Q 4* (*a*) *An approximately rectangular waveform consists of the following frequency components:*

(*i*) *1 kHz, of amplitude 1 V peak-to-peak,*
(*ii*) *3 kHz, of amplitude 0·33 V peak-to-peak, and*
(*iii*) *5 kHz, of amplitude 0·2 V peak-to-peak.*

*Sketch the components to show how they add to form the required waveform.*

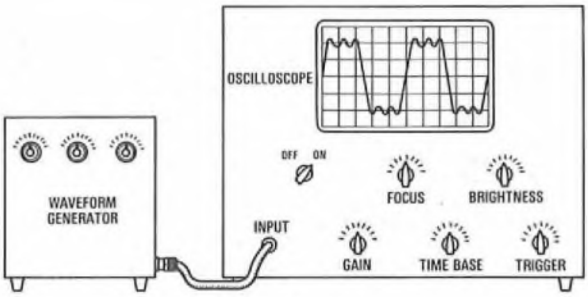
(*b*) *Describe, with the aid of a sketch, how the above waveform is displayed on an oscilloscope, indicating the sequence of adjustments necessary to provide a stable and clear trace.*

A 4 (*a*) Sketch (*a*) shows the 3 components and their resultant. The resultant can be seen to approximate to the required rectangular waveform.



(*a*)

(*b*) Sketch (*b*) illustrates how the waveform can be displayed on an oscilloscope. The oscilloscope is turned on and allowed to warm up, and the waveform generator is connected to the oscilloscope's input. The TIME BASE control is adjusted to a suitable value, say 0·2 ms/division, and the GAIN control is set to give a display that fills the screen, say 0·2 V/division.



(*b*)

The TRIGGER control is adjusted until a stable trace appears on the screen, and the FOCUS and BRIGHTNESS controls adjusted until a clear display is obtained.

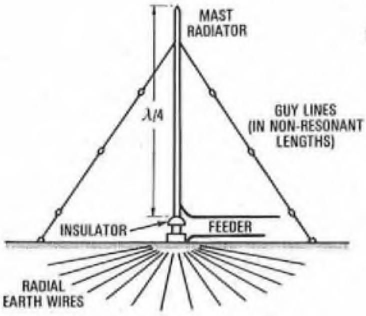
Q 5 (*a*) *With the aid of a diagram, describe the principle of operation of a unipole aerial, and sketch its radiation pattern.*

(*b*) *Suggest a suitable feeder for the above aerial and describe the method of matching.*

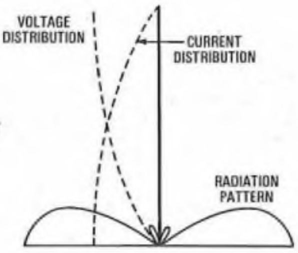
(*c*) *Explain any similarity between the unipole and the dipole aerial.*

(*d*) *State one application of the unipole aerial.*

A 5 (*a*) A unipole aerial is illustrated in sketch (*a*). It is a vertical aerial with a length equal to $\lambda/4$ metres, where $\lambda$ is the working wavelength (metres), and is used for long-wave and medium-wave transmissions.



(*a*)



(*b*)

The feed is between the bottom of the mast, which is insulated from the ground, and a horizontal conducting plane, the latter being made up of a number of earth wires radial to the axis of the aerial. The principle is that the conducting plane produces an image below the ground, so that the aerial appears as a dipole.

The aerial produces vertically-polarized surface waves that travel along the earth's surface. The voltage and current distributions and radiation pattern are shown in sketch (*b*).

This form of aerial can also be used at very high frequencies (VHF) when mounted at the top of a mast with a conducting plane, or *counterpoise*, of earthed radial wires suspended below it.

(*b*) Although at VHF a suitable feeder is a coaxial cable, at low frequencies an open-wire feeder is commonly used. Since the aerial's impedance is about 37 Ω, a suitable transformer is needed to match it to a coaxial cable. Quarter-wave stubs can also be used for matching.

(*c*) The similarity between unipole and dipole aerials arises from the fact that a unipole is a dipole with the lower arm formed by the virtual image below the conducting plane. Both aerials require a low-impedance current feed, and have similar voltage and current distributions and radiation patterns.

(*d*) Unipole aerials are commonly used for broadcasting at long or medium wavelengths, and for emergency-service communications at VHF.

Q 6 (*a*) *Describe 2 methods of obtaining long-distance radio communication at frequencies below 300 MHz.*

(*b*) *Tabulate the essential differences between the 2 methods described in terms of carrier frequency, type of propagation, the service provided and transmitter power requirements.*

A 6 See A6, Radio and Line Transmission B, 1973, *Supplement*, Vol. 68, p. 10, Apr. 1975.

Q 7 (*a*) *An amplifying tube has a single resonant circuit for its anode load as shown in Fig. 1.*

*Derive a formula for the maximum gain of the stage, assuming the mutual conductance of the tube to be $g_m$ and the anode (a.c.) resistance to be high compared with the impedance of the circuit.*

(*b*) *Calculate*

(*i*) *the bandwidth of the circuit at the half-power points,*
(*ii*) *the gain-bandwidth product of the stage, and*
(*iii*) *the maximum gain of the amplifier,*

*given that $g_m = 1$ mS, $L = 3{\cdot}68$ mH, $R = 230\ \Omega$, and $C = 200$ pF.*

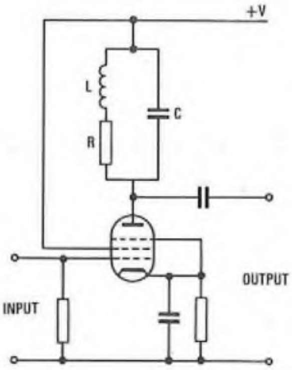
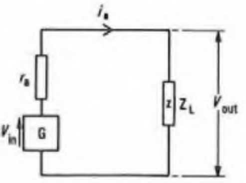


*Fig. 1*



(*a*)

A 7 (*a*) The equivalent circuit of the amplifier is shown in sketch (*a*), where $Z_L$ represents the impedance of the tuned circuit comprising the anode load (ohms). The tube is represented by the anode (a.c.) resistance, $r_a$ ohms, in series with a voltage generator, $-\mu V_{in}$ volts, where $\mu$ is the amplification factor of the tube, and $V_{in}$ is the input voltage. The current in the circuit, $i_a$ amperes, is given by

$$i_a = -\frac{\mu V_{in}}{r_a + Z_L} \text{ amperes,}$$

and the output voltage, $V_{out}$ volts, is given by

$$V_{out} = i_a Z_L \text{ volts.}$$

Hence, the voltage amplification, $A$, is given by

$$A = \frac{V_{out}}{V_{in}} = -\frac{i_a Z_L \mu}{i_a(r_a + Z_L)} = -\frac{\mu Z_L}{r_a + Z_L}.$$

Now, $\mu = g_m r_a$

$$\therefore\ A = -\frac{g_m r_a Z_L}{r_a + Z_L}.$$

Since $r_a$ is large compared with $Z_L$, the expression becomes

$$A = -\frac{g_m r_a Z_L}{r_a} = -g_m Z_L.$$

For a constant value of $g_m$, the expression is a maximum when $Z_L$ is a maximum. For a parallel circuit, this occurs at resonance, when the impedance of the circuit becomes the dynamic impedance; that is, when $Z_L = L/CR$, where $L$ is the inductance (henrys), $C$ is the capacitance (farads), and $R$ is the resistance (ohms),

$$\therefore\ A_{max} = -\frac{g_m L}{CR} \qquad \ldots\ldots (1)$$

and this occurs at the resonant frequency of the parallel tuned anode load. The minus sign indicates that the tube produces a phase change of 180°.

*Note:* The term *gain* in the question has been interpreted as meaning the voltage amplification, since the power gain (to which that term normally refers) cannot be calculated from the given data.

(*b*) At resonance, the reactance of the inductor and capacitor are equal. Hence,

$$2\pi f_0 L = \frac{1}{2\pi f_0 C},$$

where $f_0$ is the resonant frequency (hertz).

$$\therefore\ f_0 = \frac{1}{2\pi \times \sqrt{(LC)}} \text{ hertz,}$$

$$= \frac{1}{2\pi \times \sqrt{(3{\cdot}68 \times 10^{-3} \times 200 \times 10^{-12})}} \text{ Hz} = 185{\cdot}5 \text{ kHz.}$$

The $Q$-factor of the resonant circuit is given by the ratio of the inductive reactance to the resistance. Hence,

$$Q = \frac{2\pi f_0 L}{R},$$

$$= \frac{2\pi \times 185{\cdot}5 \times 10^3 \times 3{\cdot}68 \times 10^{-3}}{230} = 18{\cdot}65.$$

The half-power bandwidth of the circuit, $B$ hertz, is given by

$$B = \frac{f_0}{Q} \text{ hertz},$$

$$= \frac{185{\cdot}5 \times 10^3}{18{\cdot}65} \text{ Hz} = \underline{9{\cdot}95 \text{ kHz.}}$$

Substituting the given values in equation (1), and ignoring the sign,

$$A_{\max} = \frac{1 \times 10^{-3} \times 3{\cdot}68 \times 10^{-3}}{200 \times 10^{-12} \times 230} = \underline{80.}$$

The gain-bandwidth product

$$= A_{\max} \times B \text{ hertz},$$

$$= 80 \times 9{\cdot}95 \times 10^3 \text{ Hz} = \underline{796 \text{ kHz}}$$

*Q 8* (*a*) *Explain the following types of noise arising in communication systems:*

(*i*) *thermal-agitation noise,*
(*ii*) *shot-effect noise,*
(*iii*) *microphonic noise,*
(*iv*) *intermodulation noise, and*
(*v*) *discharge noise.*

(*b*) *Describe one method of reducing or suppressing each type of noise.*

A 8 (*a*) (*i*) Thermal-agitation noise occurs in all conductors, and is caused by the random movement of electrons in the conductor. The noise has a uniform power/frequency spectrum and is proportional to the absolute temperature of the conductor. The noise-power level, $P_n$ watts, is given by

$$P_n = KTB \text{ watts},$$

where $K$ is Boltzmann's constant (equal to $1{\cdot}38 \times 10^{-23}$ J/K), $T$ is the absolute temperature (kelvins), and $B$ is the bandwidth (hertz).

(*ii*) Shot-effect noise in a thermionic tube is the result of fluctuations in cathode emission due to the random distribution of electrons. Although cathode current may be indicated as a steady direct current, superimposed on this are small variations due to the characteristics of electron flow. Since these variations are entirely random, the resultant noise-power/frequency spectrum is again uniform.

(*iii*) Lack of rigidity of an electrode in a tube can cause modulation of the electron stream when the tube suffers vibration. The effect is known as *microphony*, and can occur in both high-frequency and low-frequency amplifiers.

(*iv*) When a signal consisting of 2 or more frequency components passes through a non-linear device, such as a tube or transistor operated at high signal levels, mixing products of the signals can occur; that is, the sum and difference frequencies, and their harmonics, can be present. The unwanted components in the output are termed *intermodulation noise*.

(*v*) Discharge noise is the result of interference by electrical discharges or sparking. The interference can be either man-made, resulting from poorly-suppressed electric motors and car-ignition systems, or occur naturally, due to lightning discharges during thunderstorms.

(*b*) (*i*) Thermal-agitation noise can be reduced either by reducing the temperature of the conductor or by reducing the circuit bandwidth using a filter.

(*ii*) Since shot-effect noise is a fundamental mechanism, little can be done to reduce its effect.

(*iii*) Microphonic noise can be reduced by improved design, ensuring that the electrodes are held more rigidly in the tube. Its effect can be reduced by using a shock-absorbent mounting. Transistor amplifiers do not suffer from microphonic noise and provide a means of avoiding the effect.

(*iv*) Intermodulation noise can be reduced by applying negative feedback across the affected stage, or by reducing the amplitude of the applied signals so that the stage operates in the linear portion of its characteristics. The former solution is usually adopted as it allows larger amplitude signals to be used.

(*v*) Man-made discharge noise must be suppressed at source by suitable filters and capacitors. Little can be done to reduce naturally-occuring discharge noise apart from using the minimum possible bandwidth for the system requiring protection.

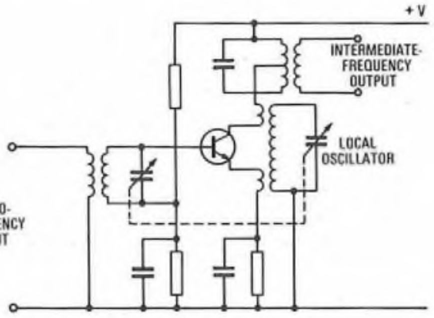
*Q 9* (*a*) *Draw the circuit diagram and describe the operation of a frequency changer (including the local oscillator) for use in a superheterodyne receiver.*

(*b*) *Describe how the oscillator works.*

(*c*) *State the type of mixing that takes place.*

(*d*) *List the frequency products that can occur in a frequency changer, and explain the steps taken to select the required signal.*

A 9 (*a*) The circuit diagram of a frequency changer for use in a superheterodyne receiver is shown in the sketch. The circuit illustrated uses a single transistor for both oscillator and mixing functions, and is commonly employed in receivers because it is cheap and provides good frequency stability.



The incoming radio-frequency (RF) signal is fed to the base of the transistor via a tuned circuit, base bias being introduced at the decoupled side of the tuned circuit's secondary winding. In the transistor, the signal is mixed additively with the local-oscillator signal, the latter being maintained by the collector–emitter feedback via the oscillator's tuned circuit. The wanted intermediate-frequency (IF) signal is selected by the tuned circuit in the collector load.

The tuned circuit in the base circuit and the local-oscillator's tuned circuit have their tuning capacitors ganged together so that a constant IF is generated as the mixer is tuned to different input frequencies.

(*b*) When the circuit is first switched on, the transistor is biased in the class-A mode, providing a high gain. Noise at the input of the transistor is amplified, inducing a signal from the collector circuit into the oscillator's tuned circuit. This signal is fed back to the emitter circuit and further amplified. As oscillations build up, rectification of the oscillating voltage at the emitter causes a steady voltage to be set up across the emitter resistor, thus biasing the amplifier into class-B operation and stabilizing the oscillator. This action also provides the optimum non-linear conditions for mixing.

(*c*) For the transistor mixer described, the type of mixing that takes place is called *additive*.

(*d*) The frequency products that can occur in the output of a mixer are

(*i*) the RF input signal, having a frequency $f_s$ hertz,
(*ii*) the local-oscillator signal, having a frequency $f_0$ hertz,
(*iii*) the sum frequency, $f_s + f_0$ hertz,
(*iv*) the difference frequency, $f_s - f_0$ hertz, and
(*v*) harmonics of the above signals.

It is usual to select the difference frequency as the IF signal. This is achieved by a resonant circuit tuned to this frequency in the collector circuit. The resonant circuit has a high $Q$-factor to provide good selectivity, and the collector is connected to a tapping on the tuned circuit primary winding so that the output resistance of the transistor does not load the resonant circuit.

*Q 10* (*a*) *Describe, with the aid of a circuit diagram, the operation of either a cathode follower or an emitter follower.*

(*b*) *Show how negative feedback is obtained in the circuit described.*

(*c*) *What effect has the negative feedback on the input and output impedances?*

(*d*) *Describe one example of the use of either a cathode or an emitter follower.*

A 10 For a description of the cathode follower, see A7, Radio and Line Transmission B, 1970, *Supplement*, Vol. 64, p. 68, Oct. 1971.

For a description of the emitter follower, see A10, Radio and Line Transmission B, 1973, *Supplement*, Vol. 68, p. 12, Apr. 1975.

## TELEPHONY B, 1975

**Students were expected to answer any 6 questions**

*Q 1 (a) For each of the following types of call, draw a simple trunking diagram to identify the points from which transmitter-feeding current is supplied to each telephone:*

*(i) a local call in a non-director exchange,*
*(ii) a local call in a director exchange,*
*(iii) a call from one non-director exchange to another, and*
*(iv) a call from one director exchange to another.*

*(b) With the aid of sketches, describe 2 different methods of supplying transmitter-feeding current to both telephones.*

*(c) At what points would transformer-type bridges offer advantages over capacitor-type bridges?*

*Q 2 (a) Compare the relative advantages of a cordless PMBX, a cord-type PMBX, and a PABX.*

*(b) With the aid of sketches of the circuit elements concerned, explain how the following are used in a PBX to signal a call incoming from the public exchange:*

*(i) a drop-flap indicator, and*
*(ii) a relay and lamp.*

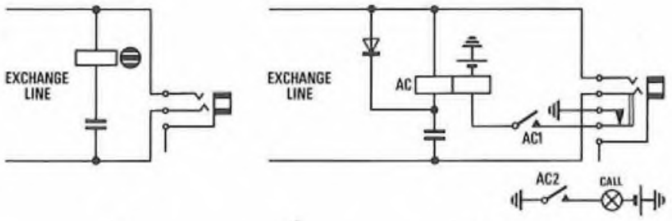
A 2 (*a*) Cordless PMBXs are limited to relatively small installations. They are compact and present no accommodation problems.

Cord-type PMBXs are available in single-position or multipled versions to cover a wide range of numbers of extensions, exchange lines and private circuits. The switchboards are normally floor-standing and are relatively bulky. Large installations require a separate switchroom.

Since all calls on cordless and cord-type PMBXs are controlled by an operator, it is possible to give priority to certain extensions and bar certain originating calls.

Full automatic service is available at all times on extension–extension and extension–exchange calls on a PABX. These calls can be set up more quickly than on a PMBX, and fewer operators are needed. Some small installations are subscriber-assisted and do not require a specialist operator. PABXs are available to cover a wide range of sizes of installation.

(*b*) Sketches (*a*) and (*b*) respectively show the drop-flap-indicator and relay-and-lamp methods of signalling an incoming call at a PMBX.



(*a*) (*b*)

In a drop-flap indicator, an armature extension normally latches a flap, or shutter, in the upright (closed) position. Ringing current vibrates the armature, and the shutter is released to display the number of the calling exchange line. In the simplest form of indicator, the shutter is relatched by the operator after answering the call.

In the relay-and-lamp circuit, the diode assists relay AC to operate to ringing current by ensuring that current flows through it in only one direction. Contact AC1 holds relay AC over a second winding, and contact AC2 lights the CALL lamp associated with the exchange-line jack. When the operator inserts an answering plug, the holding circuit for relay AC is broken, and the CALL lamp is extinguished.

*Q 3 (a) Three self-contained non-director exchanges, A, B and C, are each 8 km distant from the other 2 exchanges.*

*(i) What are the possible methods of routing calls from exchange A to exchange B?*

*(ii) What are the relative line and equipment cost considerations of these methods?*

*(b) Why is the choice of routing influenced by the density of traffic on the various routes?*

A 3 (*a*) (*i*) The possible methods of routing calls from exchange A to exchange B are over direct junctions, or over indirect junctions using exchange C as a tandem switching centre.

(*ii*) Each directly-routed call occupies 8 circuit km, compared with a total of 16 circuit km for an indirectly-routed call. Hence, direct routing has a 2 : 1 line-cost advantage over indirect routing.

Indirect routing requires that exchange C be provided with a group selector to terminate each incoming A–C junction, and an auto-auto relay-set for each outgoing C–B junction. These are additional to the equipment needed at exchanges A and B for a direct route.

(*b*) The density of traffic on a junction route affects the cost. A large group of junctions carrying dense traffic is more efficient than a smaller group carrying light traffic. The average busy-hour traffic per circuit rises with the size of a junction group, without affecting the grade of service.

Thus, the choice of routing is affected by the density of A–B and C–B traffic. If the traffic on both these routes is light, the concentration of the traffic onto a common C–B route raises the traffic density of that route. The resulting effective saving of circuits could offset the extra cost of indirect routing.

However, if the A–B traffic is heavy, it is less likely that a further significant increase in average traffic per circuit could be made by using indirect routing, particularly if the C–B traffic is relatively light.

*Q 4 For a step-by-step director system,*

*(a) describe, with the aid of a trunking diagram, the sequence of operations on a call routed via a tandem exchange,*

*(b) explain why, in the case of a local call, there is a significant delay between the end of dialling and the receipt of ringing tone, and*

*(c) explain why existing local directors cannot be used to route dialled trunk calls.*

A 4 (*a*) See A5, Telephony B, 1970, *Supplement*, Vol. 64, p. 19, Apr. 1971.

(*b*) See A3, Telephony B, 1969, *Supplement*, Vol. 63, p. 23, Apr. 1970, and A4, Telephony B, 1972, *Supplement*, Vol. 66, p. 19, Apr. 1973.

(*c*) For an inland trunk call, a routing code of up to 4 digits, and an exchange number of up to 6 digits, may be dialled. A register-translator, connected to a level of the A-digit selector, would have to receive and process 9 of these digits. However, existing local directors can receive and process only 6 digits, and therefore cannot be used to route trunk calls.

*Q 5 (a) Two subscribers, X and Y, share a line to an automatic exchange. Explain how*

*(i) selective ringing is arranged on incoming calls, and*
*(ii) separate metering is arranged on outgoing calls.*

*Illustrate your answers with sketches of the circuit elements concerned at the subscribers' installations and at the exchange.*

*(b) Give 2 examples to show how this type of shared service can cause difficulties that are not encountered with direct exchange lines.*

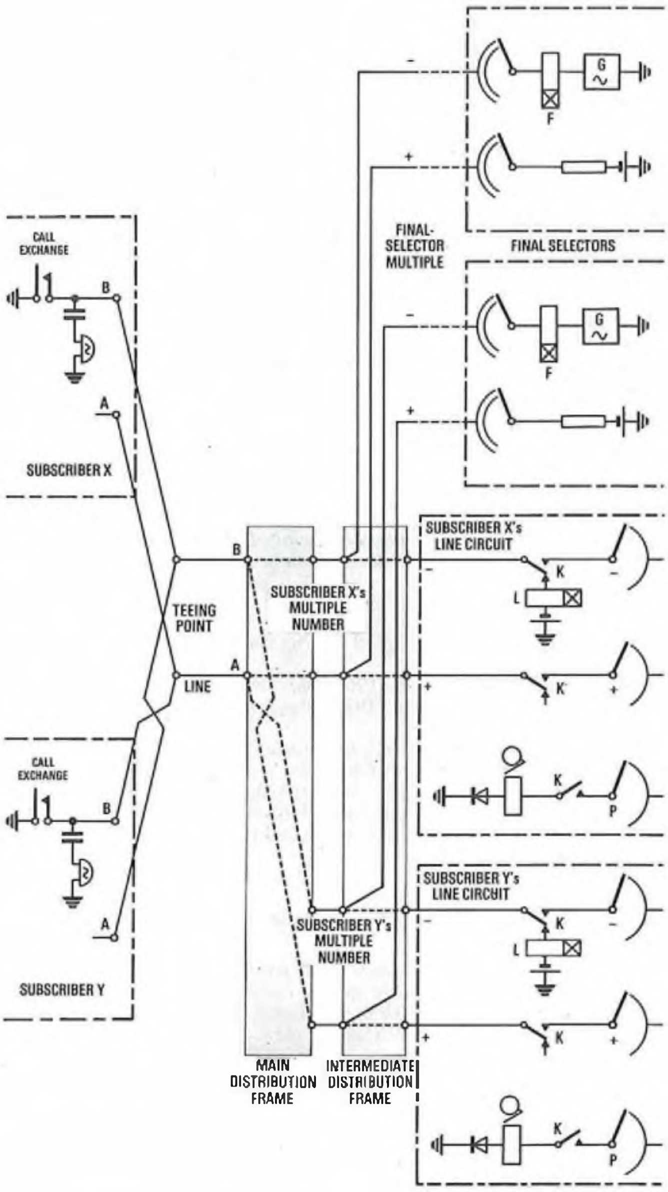
A 5 (*a*) The sketch shows the circuit elements for the selective ringing of shared-service telephones, and the selective metering of calls. The 2 telephone instruments are identical.

(*i*) *Selective Ringing* In the idle condition, each instrument has a capacitor and bell connected in series between the instrument's B-wire and earth; the A-wires are disconnected. However, at the teeing point, usually the distribution point, the connexions of subscriber Y's lead-in are reversed. Therefore, from the main distribution frame (MDF), subscriber X's bell appears on the B-wire of the line, and subscriber Y's bell appears on the A-wire. On the MDF, the jumper connecting the line to subscriber Y's multiple number is reversed.

Final selectors apply an earthed ringing supply, via their relays F, to the negative wire of the final-selector multiple. When subscriber X is called, ringing current passes from the negative final-selector-multiple wire, over the B-wire of the line, to operate subscriber X's bell. Subscriber Y's bell is unaffected. When subscriber Y is called, ringing current passes from the negative final-selector-multiple wire, over the A-wire of the line, to operate subscriber Y's bell. Subscriber X's bell is unaffected. Hence, selective ringing is achieved.

(*ii*) *Selective Metering* On the intermediate distribution frame, each subscriber's multiple number is jumpered to his designated line circuit. In the idle condition, the positive wire of each line circuit is disconnected, instead of being earthed as for direct exchange lines. Subscriber X's line relay (relay L) is connected to the B-wire of the line, as is normal practice for a direct exchange line, but subscriber Y's line relay is connected to the A-wire, due to the reversed MDF jumper.

A call is originated from either telephone by operating the non-locking CALL-EXCHANGE button to apply earth to the instrument's B-wire. Because of the reversal in his lead-in, subscriber Y's calling signal passes over the A-wire of the line to operate his own line relay. Subscriber X's calling signal passes over the B-wire to operate the line relay in the line circuit allotted to him. Since each line circuit has its own meter, calls originating from it are registered against the subscriber associated with that line circuit. Hence, selective metering is achieved.



The P-wires (not shown) on the multiple side of the line circuits are connected together so that, whichever line circuit is activated, the other is disabled by the busying earth on the common P-wire (A similar guarding condition is applied when either subscriber receives an incoming call.) The busying earth operates relay K (not shown) in the idle line circuit, thus disconnecting the line relay.

(*b*) Two examples of difficulties created by using shared-service lines are given below.

(*i*) An accidently reversed line has no effect on the working of a direct exchange line. However, on a shared-service line, the effects are serious. For example, a reversal between the teeing point and the MDF causes both subscribers' calls to be misrouted, and originating calls are registered on the wrong meters.

(*ii*) On shared-service lines, a local earth connexion must be provided at each subscriber's premises, thus increasing the fault liability of the installation. For example, if such an earth connexion develops a high series resistance, the subscriber will have difficulty making calls, and possibly receiving them.

*Q 6* (*a*) *With the aid of sketches of the circuit elements, describe the operation of any 2 of the following facilities of an auto–auto relay-set:*

(*i*) *dial-pulse repetition, including 2-stage drop-back,*

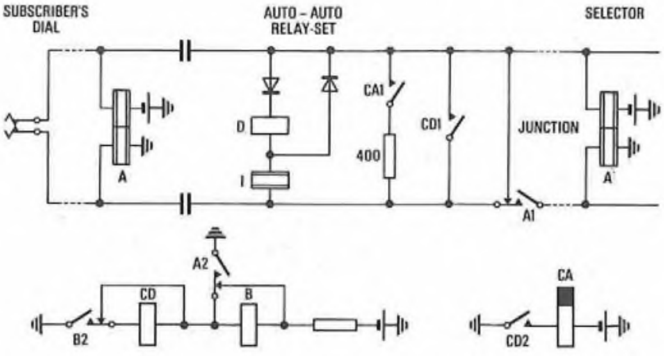
(*ii*) *backward (called-subscriber) answer signal repetition, with control of local metering, and*

(*iii*) *junction guarding.*

(*b*) *Give the approximate timing of each slugged relay mentioned in your descriptions.*

A 6 (*a*) For completeness, descriptions of all 3 functions are given.

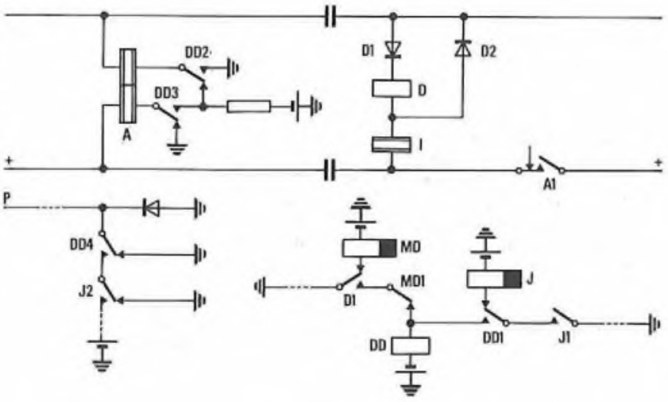
(*i*) Sketch (*a*) shows the circuit elements concerned with the repetition of dial pulses, including the 2-stage drop-back arrangement, for an auto–auto relay-set at a non-director exchange from which a call is originated. Loop-disconnect pulses from the subscriber's dial are received by relay A and repeated over the junction to the incoming selector at the distant exchange by contact A1. Relay B is operated on seizure of the relay-set, so that relay CD operates when contact A2 releases to the first *break* pulse of the pulse train. The release lags of relays B and CD are such that they remain operated during the pulse train. Contact CD2 operates relay CA, and contact CD1 provides a low-resistance loop for the pulses generated by contact A1.



(*a*)

At the end of each pulse train, relay A remains held and contact A2 short-circuits relay CD, which releases slowly. Contact CD1 disconnects the low-resistance pulsing loop, but contact CA1 maintains a 400 Ω shunt across the inductive retarding coil of relay I. Contact CD2 disconnects relay CA, which releases slowly. Contact CA1 then disconnects the 400 Ω shunt from the inductive part of the circuit.

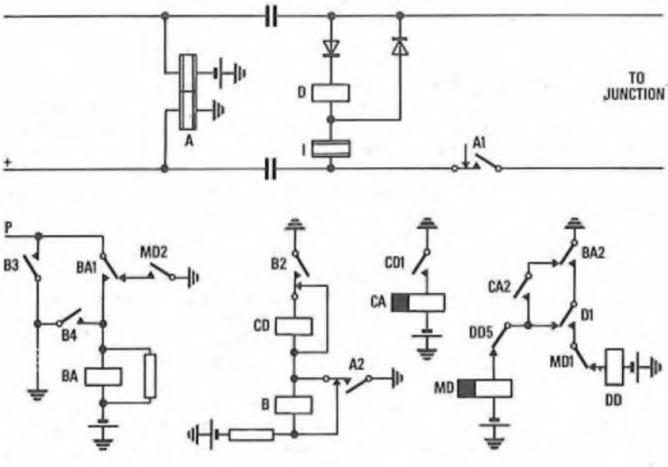
The sequencing of contacts CD1 and CA1 is called *2-stage drop-back*. Its purpose is to provide a holding path, via the 400 Ω shunt, for relay A at the distant exchange's incoming selector during the initial rise of current in relay I, following the disconnexion of the pulsing loop. The low initial value of current in relay I would otherwise allow relay A to release momentarily, thereby creating a false dial pulse.



(*b*)

(*ii*) Sketch (*b*) shows the circuit elements concerned with repeating the *called-subscriber-answer* signal and registering the call. The *called-subscriber-answer* signal returned over the junction is a reversal of the line polarity. Diode D1 is thus forward-biased, and relay D operates. Contact D1 releases relay MD slowly, and contact MD1 operates relay DD. Contacts DD2 and DD3 reverse the polarity of the incoming negative and positive wires to repeat the *called-subscriber-answer* signal (possibly to a manual switchboard). Contact DD4 connects positive battery to the incoming P-wire, and this condition initiates registration of the call, either directly over the P-wire to the subscriber's meter, or via local-call-timing equipment. Up to this point, relay J has been held operated by contact J1, but the holding circuit is now disconnected at contact DD1, and relay J releases slowly. Contact J2 then disconnects positive battery from the P-wire.

(*iii*) Sketch (*c*) shows the circuit elements concerned with providing a long junction-guarding period when the calling subscriber clears down. Relay A releases when the calling loop is broken, and contact A1 repeats the *forward-clearing* signal to initiate release of the selectors at the distant exchange. Contact A2 operates relay CD and releases relay B. Contact CD1 operates relay CA. Contact B2 initiates the slow release of relay CD, while contacts B3 and B4 initiate the somewhat faster release of relay BA and, at the same time, remove the holding-and-guarding earth from the incoming P-wire. This releases the preceding selectors. When relay BA releases, contact BA1 reguards the P-wire from the earth at contact MD2. Relay MD, which was previously operated, is now controlled by contact CA2, and is released slowly when relay CA releases, thus removing the reguarding earth. Hence, the long junction-guarding period consists of the total release times of relays CD, CA and MD, less the release time of relay BA.



(*c*)

(*b*) The approximate release times of the slow-to-release relays are:

B — 250 ms,
CD — 100 ms,
CA — 250 ms,
MD — 200 ms,
J — 250 ms,
BA — 30 ms.

*Q 7 (a) Estimate the times required by a 2-motion group-selector to perform its several inter-digital functions, and compare the total time with the inter-digital time of a subscriber's telephone.*

*(b) Does the risk of call failure from rapid dialling differ between director and non-director systems? Give reasons for your answer.*

*(c) What determines the time required by a succeeding selector to prepare to receive dial pulses?*

A 7 (*a*) The inter-digital functions of a 2-motion group selector, and their durations, are

(*i*) detecting the end of a pulse train by the slow release of relay CD, taking 100 ms,

(*ii*) stepping horizontally and testing each outlet (or pair of outlets) until a free outlet is found, taking 30 ms for one step or 300 ms if hunting continues to the last outlet, and

(*iii*) guarding the free outlet and switching the call through to the next stage by the re-operation of relay CD, taking 20 ms.

Hence, the total time taken, assuming hunting continues to the last outlet, is 420 ms. This is a maximum value, and occurs only during busy periods. If the first outlet is free, the total time is 150 ms.

The built-in lost-motion period of a dial provides a pause of about 200 ms between the release of the dial plate from the finger stop and the first *break* pulse to be transmitted. Before this, the user has to wind up the dial, and the speed of this depends on the selected digit and the experience of the user. Only very experienced users, such as PBX operators, are likely to complete the winding action in less than 220 ms to give a total pause less than the maximum estimated inter-digital time for the selector.

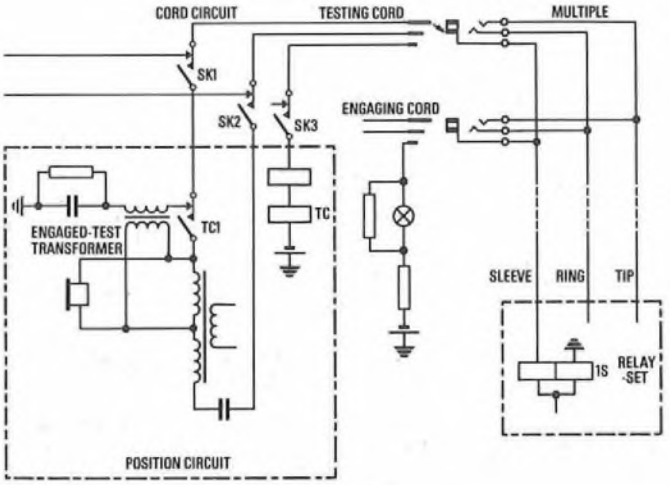
(*b*) In the non-director step-by-step system, all selectors are directly controlled by the subscriber's dial. Under a combination of adverse conditions, there is the risk of failure of the call when a series of digits such as 222 is dialled by an experienced user. In the director step-by-step system, only the A-digit selector and director are controlled by the subscriber's dial, and the registers in the director have no inter-digital hunting to perform. The first code-selector, and all subsequent selectors, are controlled by the director, which gives a pause of about 600–800 ms between each pulse train. The risk of call failure is therefore less in the director system.

(*c*) The time to prepare a selector to receive dial pulses, after a call has been switched through to it, is determined by cumulative operate times of relays A, B and CD.

*Q 8 (a) With the aid of a diagram of the circuit elements concerned, explain how the operator at a sleeve-control auto-manual switchboard position can make an* ENGAGED *test with the tip of a calling plug.*

*(b) With the aid of a diagram, explain how a lamp can be lit to indicate the first free circuit in a group of circuits.*

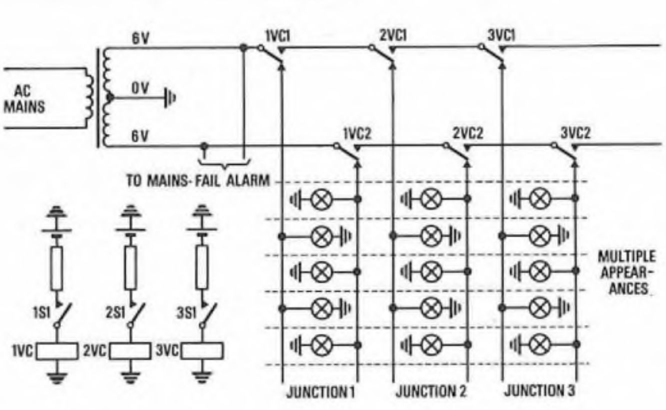
A 8 (*a*) In the idle condition, the sleeve of a multipled circuit at a sleeve-control auto-manual switchboard is at earth potential. Sketch (*a*) shows how the sleeve acquires a negative potential when an engaging cord is inserted in one of the jacks.



(*a*)

The purpose of an ENGAGED test is to ascertain whether a circuit is free or busy. The SPEAK key of the testing cord circuit is operated, operating relay SK (not shown) and extending the tip, ring and sleeve wires to the position circuit. Relay TC is normal, so that the tip wire is extended to the primary winding of the engaged-test transformer. The secondary winding is connected to the operator's telephone circuit.

The tip of the testing cord is brought into contact with the sleeve of the jack to be tested. If the circuit is busy, a small current flows in the primary winding of the engaged-test transformer. The voltage surge produced across the secondary winding as the primary current rises is applied to the receiver, and the operator hears a click. Further clicks can be heard each time the tip of the testing cord is disconnected and reconnected to the sleeve of the jack. If the circuit is free, no current flows, and the operator hears nothing.



(*b*)

(*b*) Sketch (*b*) shows the principle of a free-line-signalling (FLS) system that indicates to switchboard operators which of a group of circuits should be used for the next outgoing call. The circuit indicated is the lowest-numbered free circuit.

Each jack appearance of a multipled junction has an associated

FLS lamp. The lamps are controlled by relays VC, which in turn are controlled by relays S of the junction relay-sets. When a junction is busy, relay VC associated with that junction is operated and the FLS lamps are disconnected. If junctions 1 and 2 are busy, and junction 3 is free, the supply is extended to the FLS lamps of junction 3. If junction 1 subsequently becomes free, contacts 1VC1 and 1VC2 transfer the FLS to the first choice.

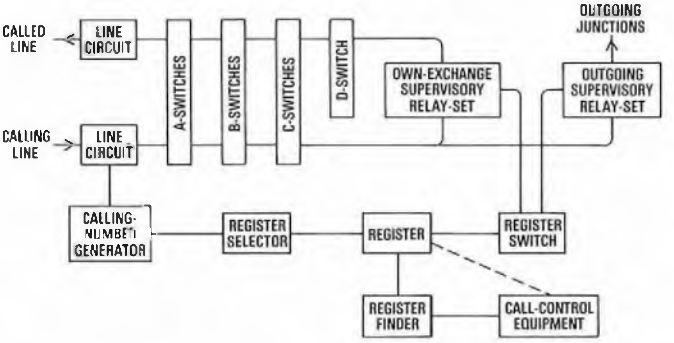
While the FLS system is working, there is no need for operators to make ENGAGED tests. Should the mains supply fail, an alarm is given, and manual ENGAGED tests have to be resumed.

*Q 9 (a) Draw a simple block diagram of a TXE2 (reed-relay) electronic exchange.*

*(b) Explain how dial tone is returned to the caller.*

*(c) What determines the type of supervisory relay-set assigned for the initial dial-tone path?*

A 9 (*a*) The sketch shows a simple block diagram of a TXE2 exchange.



(*b*) When a subscriber calls the exchange, his line circuit sends a pulse to the calling-number generator (CNG) over a wire that identifies the calling line. The CNG generates the subscriber's directory number, coded in a 2-out-of-5 form. This information is passed to a free register via the register selector. The register applies to the call-control equipment for a free supervisory relay-set, to which it is connected via the register switch. The call-control equipment directs the selection of suitable A-switch–B-switch and B-switch–C-switch links to connect the calling subscriber from his A-switch inlet to the allocated supervisory relay-set on a C-switch outlet. A path is then completed from the calling-subscriber's line, via the A-switch, B-switch, C-switch, supervisory relay-set and register switch, to the register. The calling subscriber receives dial tone from the register.

(*c*) A calling subscriber may require an outgoing supervisory relay-set to route his call over a junction to another exchange, or an own-exchange relay-set to connect the call to another subscriber on the same exchange. The type of relay-set initially allocated for all originating calls is that for the route carrying most of the originated traffic, and is determined by traffic studies and programmed into the call-control arrangements. If the digits dialled into the register indicate that the relay-set required is not of the predetermined type, the calling line is reconnected to one of the correct type. Reconnexion is carried out very rapidly during an inter-digital pause, and does not affect the subscriber's dialling operations.

*Q 10 (a) What are the electrical characteristics of*

*(i) ringing current, and*
*(ii) ringing tone?*

*(b) Outline the principle of operation of a machine capable of generating both ringing current and ringing tone.*

*(c) If the maximum number of lines to be rung simultaneously at an exchange is 150, and each connexion takes 20 mA at 75 V r.m.s., estimate the required power rating of the ringing machine. (Ignore the power factor.)*

A 10 (*a*) Ringing current is a low-frequency (17 Hz or 25 Hz) supply with an amplitude of about 75 V r.m.s. Ringing tone is a mixture of 400 Hz and 450 Hz tones, and has an amplitude of about 1 V r.m.s.

Both supplies are interrupted to give a repeated sequence of 400 ms on, 200 ms off, 400 ms on, and 2 s off.

(*b*) A suitable generator has, on a common shaft, a shunt-wound d.c. motor, a low-frequency alternator to produce continuous ringing current, and a pair of induction-type generators to produce continuous 400 Hz and 450 Hz supplies.

The d.c. motor is driven from the exchange battery, and its armature carries not only the motor winding but also the alternator winding, connected via slip rings. During each revolution, the alternator winding passes the 2 poles of a common stator and generates 1 cycle of ringing current. When the shaft revolves at 25 rev/s, the alternator generates 25 Hz.

Each of the induction-type generators has a multiple-toothed stator, the upper and lower halves of which form the pole pieces of a permanent magnet. A multiple-toothed laminated rotor of a magnetic material revolves inside each stator. As one tooth of the rotor passes one tooth of the stator, the flux density in the stator tooth rises and falls. Each rise and fall of flux density produces 1 cycle of alternating current in a stator winding that encircles each tooth, by virtue of the change in flux linkages. With a rotor of 16 teeth revolving at 25 rev/s, a 400 Hz tone is generated; for the 450 Hz tone, 18 teeth are used.

(*c*) Ringing-current supplies are distributed to the exchange equipment in such a way that the total load is almost equally divided between 3 separate distribution circuits. Each distribution circuit is fed via interrupting contacts operated by cams on the shaft of the generator. The contacts not only provide the correct sequence of 400 ms on, 200 ms off, 400 ms on and 2 s off, but also ensure that only one distribution is connected to the generator at any time by phasing the 1 s active period of each distribution to fall within the 2 s inactive periods of the other two. Hence, the number of lines simultaneously requiring ringing current is one third of the total; that is 50 lines.

The rating of the generator is given by the voltage multiplied by the current taken by one line multiplied by the number of lines. Therefore, the rating

$$= 75 \times 20 \times 10^{-3} \times 50 = \underline{75\ \text{W}}.$$

## CORRECTION

### TELEPHONY B, 1974 (*Supplement*, Vol. 68, July 1975)

A 2 (*b*) (*i*) The cam bank is not raised to different heights for 2p and 10p coins, as implied. The number of coin pulses generated is determined by a coin lever, associated with the coin slot used, which moves a pivoted pulsing spring-set opposite to the cam appropriate to that value of coin.

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# TELEGRAPHY B, 1975

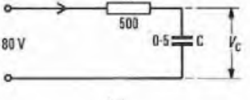
**Students were expected to answer any 6 questions**

*Q 1 (a) A battery of +80 V is applied to a circuit consisting of a resistor of 500 Ω in series with a capacitor of 0·5 μF. Plot graphs to show how*

*(i) the current in the circuit varies with time, and*
*(ii) the voltage across the capacitor varies with time.*

*(b) What is the significance of these graphs for the transmission of telegraph signals by direct current?*

A 1 (*a*) The circuit is shown in sketch (*a*). When the battery is first applied, the capacitor acts as a short-circuit, and the voltage across the capacitor, $V_C$ volts, is zero. After infinite time, the capacitor appears open-circuit, and $V_C = V = 80$ V, where $V$ is the supply voltage. The time taken for $V_C$ to rise to 0·6321 of its final value is known as the *time constant* of the circuit, and is equal to $CR$ seconds, where $C$ is the capacitance (farads), and $R$ is the resistance (ohms).



(*a*)

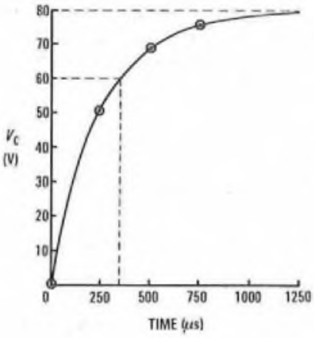
Now, $CR = 500 \times 0{\cdot}5 \times 10^{-6}$ s $= 250$ μs.

After 250 μs, $V_C = 0{\cdot}6321 \times V = 0{\cdot}6321 \times 80 = 50{\cdot}6$ V.

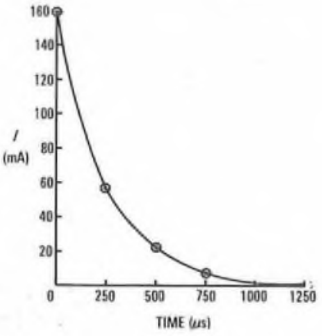
After a further 250 μs, $V_C$ has increased by $0{\cdot}6321 \times (80 - 50{\cdot}6)$ V to 69·2 V.

After a further 250 μs, $V_C$ has increased by $0{\cdot}6321 \times (80 - 69{\cdot}2)$ V to 76 V.

The points calculated above are sufficient to plot the graph shown in sketch (*b*).



(*b*)



(*c*)

In a similar way, the graph for the current in the circuit, $I$ amperes, can be plotted. Initially, the capacitor acts as a short-circuit, and $I = 80/500$ A = 160 mA. After infinite time, the capactior is open-circuit, and the final value of $I$ is zero.

After 250 μs, the current has reached 0·6321 of its final value; that is, $I$ has reduced by 0·6321 × 160 mA to 58·9 mA, or to 0·3679 of its initial value.

After a further 250 μs, $I$ has reduced to 0·3679 × 58·9 = 21·7 mA. After a further 250 μs, $I$ has reduced to 0·3679 × 21·7 = 8 mA. The graph is shown in sketch (*c*).

(*b*) A short telegraph line can be represented by the network shown in sketch (*a*), with the typical values given in the question. Sketch (*b*) shows that, when an 80 V signal is connected to the line, the voltage at the distant end, $V_C$, does not immediately rise to the value of the applied voltage. If a telegraph instrument, whose receiving magnet operates at 60 V, is connected to the line, the signal is not registered until about 350 μs after its application. The receiver is therefore made slow to operate by the capacitance of the line, and the speed of signalling is reduced.

Sketch (*c*) shows that, when the signal is connected, there is a surge of current to charge the line capacitance. The maximum value of current is in excess of the current required to operate the terminal equipment, and power supplies and contacts in the circuit must therefore be adequate to supply and carry the high current.

*Q* 2 *With the aid of timing diagrams, explain the meaning of*

(*a*) *7½-unit start-stop double-current 50 baud signals,*
(*b*) *20% early start-stop distortion,*
(*c*) *25% isochronous distortion, and*
(*d*) *40% margin.*

A 2 (*a*) See A1 and A2, Telegraphy B, 1974, *Supplement*, Vol. 68, p. 33, July 1975.

(*b*) and (*c*) See A2, Telegraphy B, 1971, *Supplement*, Vol. 65, p. 4, Apr. 1972, and A4, Telegraphy C, 1974, *Supplement*, Vol. 68, p. 68, Oct. 1975.

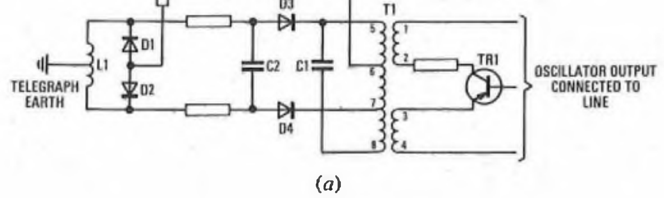
(*d*) See A2, Telegraphy B, 1973, *Supplement*, Vol. 67, p. 47, July 1974.

*Q* 3 (*a*) (*i*) *Draw a diagram to show how d.c. teleprinter signals can be converted to a.c. signals in a multichannel voice-frequency (MCVF) system.*

(*ii*) *Describe the circuit operation.*

(*b*) *Explain how more than one teleprinter circuit can be accommodated on an MCVF system.*

A 3 (*a*) (i) Sketch (*a*) shows how d.c. teleprinter signals can be converted to a.c. signals in a frequency-shift-modulated MCVF system.



(*a*)

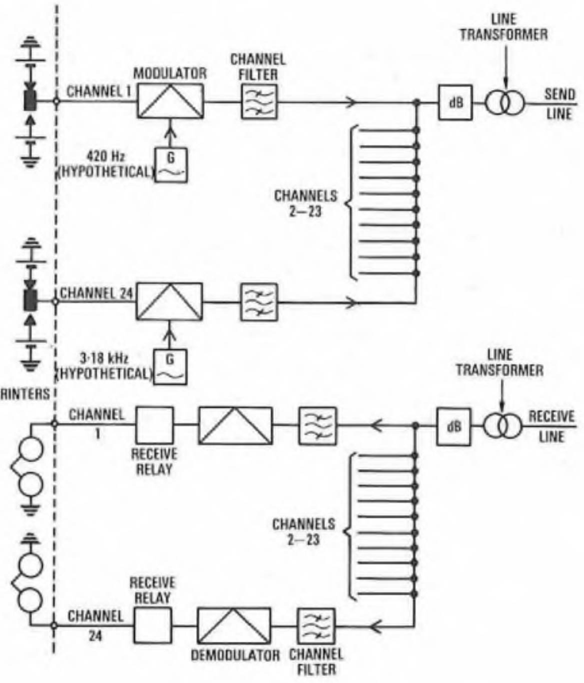
(*ii*) The modulator consists of an oscillator with a resonant circuit having components that can be switched to alter its frequency. The basic oscillator consists of transistor TR1, transformer T1 and capacitor C1. (The oscillator's amplifying circuit is not shown in detail.) The switched components are inductor L1 and capacitor C2. The oscillator's output is connected to line.

When a *mark* signal (negative potential) is connected to the SEND wire by the teleprinter, diodes D3 and D4 are forward biased from the earth at inductor L1 through windings 5–6 and 7–6 respectively of transformer T1. Diodes D1 and D2 are reverse biased, and do not conduct. Thus, inductor L1 and capacitor C2 are connected in parallel across winding 5–7 of transformer T1, lowering the frequency of the oscillator to 30 Hz below a hypothetical mean frequency.

When a *space* signal (positive potential) is applied to the SEND wire, diodes D1 and D2 conduct and, hence, diodes D3 and D4 are reverse biased. Thus, inductor L1 and capacitor C2 are isolated from the resonant circuit, and the frequency is determined only by transformer T1 and capacitor C1. These components are chosen so that the oscillator's frequency is 30 Hz above the hypothetical mean frequency.

In this way, the frequency of the a.c. signals sent to line varies by 30 Hz above and below a hypothetical carrier frequency chosen for that channel.

(*b*) Sketch (*b*) shows a method of connecting several teleprinter circuits to an MCVF system.



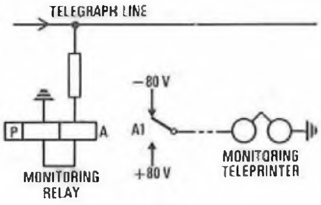
(*b*)

A telephone channel has a bandwidth of 300–3400 Hz, which can be used to accommodate up to 24 telegraph circuits, each occupying a bandwidth of 120 Hz. For each telegraph circuit, a hypothetical carrier frequency is allocated within the 300–3400 Hz band, and an oscillator is frequency-shift modulated to give frequencies of ± 30 Hz with respect to the carrier, depending on the d.c. signal applied by the teleprinter transmitter. The modulated carrier frequency is applied to a band-pass channel filter which attenuates all frequencies outside the band allocated to the channel. The signals from all 24 channels are connected to a common line and transmitted to the distant terminal, where similar band-pass filters select the frequency peculiar to each channel. A demodulator converts the ±30 Hz variations in carrier frequency to d.c. signals, which are used to operate a receive relay that can in turn control a teleprinter receive magnet.

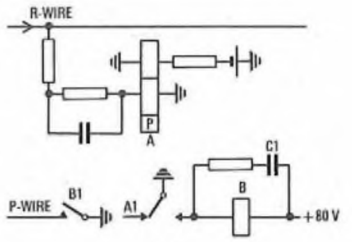
*Q* 4 *With the aid of circuit diagrams, explain the purpose and operation of each of the following on telegraph circuits:*

(*a*) *a monitoring relay,*
(*b*) *a supervisory relay,*
(*c*) *a repeating relay, and*
(*d*) *a broadcast relay.*

A 4 (*a*) Sketch (*a*) shows the connexion of a monitoring relay to a telegraph line. The monitoring relay is a sensitive relay, connected to the line through a high-value resistor, and arranged to repeat the line signals to a monitoring teleprinter. The 2 coils of the relay are connected in series to give good sensitivity, and the high series resistance ensures that a minimal amount of current is shunted from the line. The relay must repeat signals accurately and with the minimum of additional distortion. An alternative arrangement, employing a high-impedance tube circuit with a repeating relay in the anode circuit, is used for monitoring at test-desk positions (see A9 to this paper).



(*a*)



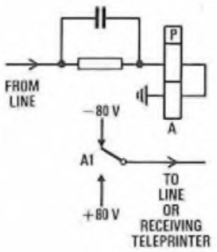
(*b*)

(*b*) Sketch (*b*) shows the circuit of a supervisory relay (relay A) in a Telex final selector. Relay A is permanently connected to the R-wire, and is used for repeating dial pulses during vertical and rotary stepping, as well as acting as a supervisory relay during the progress of a call. The relay responds to teleprinter signals on the R-wire such that contact A1 is made during *mark* signals (negative potential) and energizes relay B. Relay B remains held during *space* signals (positive potential) by virtue of the energy stored in capacitor C1. Contact B1 applies earth potential to the P-wire to hold preceding selectors.

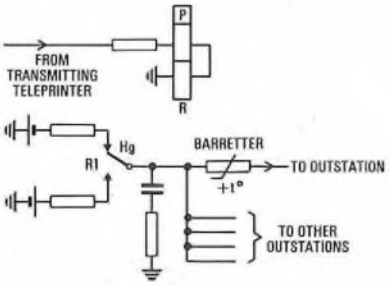
When the call is cleared, continuous positive potential is applied to the R-wire and contact A1 is broken. After a period of 325–475 ms, relay B releases and disconnects the earth potential from the P-wire to release the preceding equipment.

The supervisory relay is sensitive, and is connected to the R-wire through a high resistance to prevent impairment of the teleprinter signals. A bias winding ensures that the supervisory relay assumes the positive-potential (clearing) condition to release the selector if the line becomes disconnected during a call.

(*c*) A repeating relay, shown in sketch (*c*), is used to terminate a line section when signals may be too weak to operate the receiving teleprinter. The relay is sensitive to weak signals and retransmits each element at full amplitude as a square-wave signal. The relay does not correct any time distortion in the received signal, and should be adjusted to introduce minimal additional distortion. The relay increases the permissible speed of signalling by improving the shape of the signal.



(*c*)



(*d*)

(*d*) Sketch (*d*) shows the connexion of a broadcast relay, which is a repeating relay used in a special way. One teleprinter transmits signals to the relay, which retransmits (broadcasts) to a maximum of 10 receiving teleprinters. Because of the heavy load on the relay's contacts, a good spark-quench circuit is used. Alternatively, a mercury-wetted relay can be used for a maximum of 5 lines, as shown in sketch (*d*). A barretter is fitted to each line to protect the transmitting contacts from the effects of excess current in a faulty line.

*Q 5 (a) Why is it necessary to control the speed of a teleprinter within close limits? Outline a method by which this can be achieved.*

*(b) What other features of the teleprinter must be standardized for satisfactory working into the international Telex system?*

*Q 6 For a teleprinter keyboard, describe, with the aid of sketches, how*

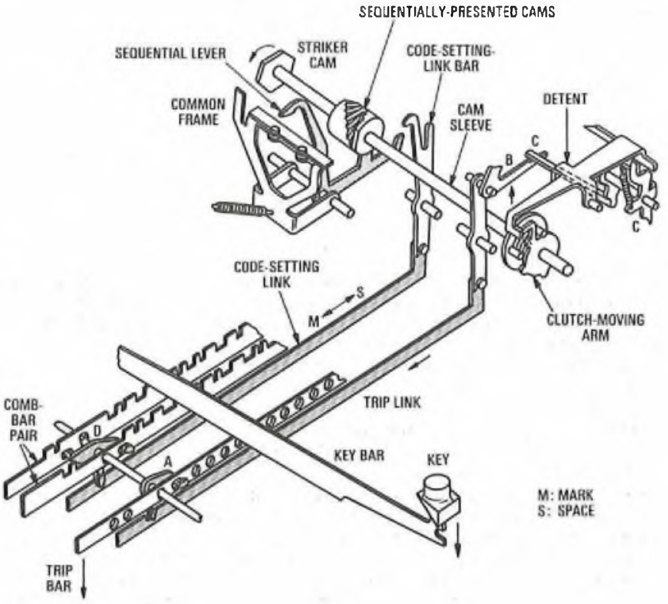
*(a) the transmitter is started when a key is depressed,*

*(b) the start element is transmitted,*

*(c) successive character elements of opposite polarity are transmitted, and*

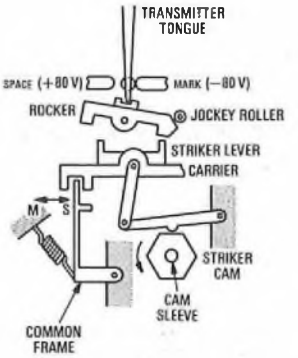
*(d) the operator is prevented from operating a second key while the first character is being transmitted.*

A 6 The illustrations shown and the descriptions given are of the British Post Office Teleprinter No. 15. Sketch (*a*) is a simplified diagram of the keyboard, showing the mechanisms for starting the transmitter when a key is depressed, and for setting one of the signalling elements.

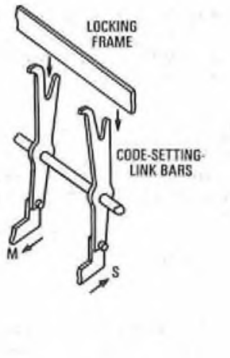


(*a*)

(*a*) When a key is depressed, the trip bar is pushed downwards so that lever A causes the trip link to move to the left. This operates levers B and C, and the upper projection to the right of lever C is pulled away from the detent, which rotates in a clockwise direction to release the clutch-moving arm. The clutch-moving arm carries one end of a spring-steel clutch band which is wound round a continuously-driven drum. A spring causes the clutch to tighten, and the drive is connected to the transmitter cam-sleeve, which begins to rotate.



(*b*)



(*c*)

(*b*) Sketch (*b*) shows the transmitter in the resting position. The cam sleeve is stationary, and the tongue is on the MARK contact from the *stop* signal of the previous character. The striker lever is positioned to the right (that is, the SPACE position) under the control of a spring acting on the common frame.

When the cam sleeve starts to revolve, the striker cam pushes the striker lever against the right-hand side of the rocker. The rocker moves past the jockey roller, and the tongue is switched to the SPACE contact to transmit the *start* signal element.

(*c*) A depressed key acts on 5 pairs of comb bars to produce the 5 signal elements. For clarity, only one pair is shown in sketch (*a*). The pair is linked by lever D, so that, as one bar moves downwards, the other moves upwards in a parallelogram-type movement. A depressed key bar engages a tooth on one bar, thus moving it downwards, and is accommodated in a corresponding notch in the other bar as it rises.

If the comb-bar pair corresponding to the first signal element is coded to produce a *mark* signal, the front bar is depressed, the rear bar rises, and lever D moves the code-setting link to the left. The top of the code-setting-link bar therefore moves to the right, allowing the corresponding sequential lever to follow one of a series of sequentially-presented cams. The common frame is therefore moved to the left by the sequential lever, the striker cam pushes the striker lever against the left-hand side of the rocker, and the tongue moves to the MARK contact.

If the comb-bar pair corresponding to the second signal element is coded to produce a *space* signal, the rear bar is depressed, the front bar rises, and the code-setting link moves to the right. The top of the associated code-setting-link bar moves to the left so that, when the sequentially-presented cam corresponding to the second element is presented, the appropriate sequential lever cannot follow it, being held off by the projection on the code-setting-link bar. The common frame therefore returns to the right as the influence of the previous sequential lever is removed, and the striker mechanism moves the tongue to the SPACE contact.

(*d*) Sketch (*c*) shows 2 of the code-setting-link bars, one set to the MARK position, and one to SPACE. As soon as the cam sleeve starts to rotate, the locking frame is lowered to lock the bars in position. This fixes the position of the code-setting links and comb bars on the keyboard. Because of the parallelogram arrangement of the comb-bar pairs, and the interfering spacing of the teeth, the operator is prevented from depressing a second key. When the character has been transmitted, the locking frame releases the keyboard.

*Q 7 (a) Describe how a telegraph message is processed by*

*(i) inland Telex, and*
*(ii) international Telex.*

*(b) Describe how a telegram is processed by*

*(i) Phonogram, and*
*(ii) Gentex.*

A 7 (*a*) (*i*) The Telex network is comparable to the public telephone network, except that a teleprinter is used at the subscriber's terminal in place of a telephone. To originate a call, the CALL button on the subscriber's control unit is operated until a lamp on the unit glows, indicating that the exchange is ready to receive dial pulses. The subscriber then operates the dial to select the wanted subscriber. When the call is connected, the *who-are-you?* signal is automatically sent from the distant exchange to the called teleprinter. The receipt of the answer-back code informs the calling subscriber that the connexion has been made and the Telex message can be transmitted. A local copy of the signals is provided on the calling teleprinter. At the conclusion of the message, answer-back codes are exchanged to ensure that the connexion has remained unbroken, and the calling-subscriber's CLEAR key is then operated. The key is depressed until the CALL lamp is extinguished, indicating that the connexion has been broken.

(*ii*) Three types of international call can be originated. For a fully automatic call using Continental Telex, the call is set up as described in part (*a*) for an inland Telex call, with the exception that the distant subscriber's number is prefixed by the appropriate code for the country. The code routes the call and determines the meter-pulse rate to be connected at the time-zone equipment in the exchange.

For a fully automatic call using the transit automatic switching centres, the call is originated as described in part (*a*), and the code 207 is dialled. This gives access to the intercontinental equipment and inhibits metering pulses, as automatic ticketing equipment is used on intercontinental calls. The ticketing equipment transmits the *who-are-you?* signal to the calling teleprinter so that the originating subscriber can be identified by recording the answer-back code. When a free transit register has been found, the characters KEY+ are transmitted from the exchange to the calling station to indicate that further selection signals should be sent from the keyboard instead of the dial; a local record is given of the selection signals transmitted. When the call reaches the distant subscriber, the answer-back code is received as for a local call and the message is sent. Answer-back codes are exchanged and the CLEAR key operated at the end of the call as for an inland connexion.

For international calls that cannot be connected automatically, a manual switchboard is provided. Certain destinations are served by cable or satellite routes, and the remainder by radio circuits, necessitating 2 separate suites of switchboards. Depending on the route required, the caller dials 201 for a radio call or 29 for a cable circuit. Each switchboard is provided with a queue and, when an incoming call is allocated a position in the queue, the characters MOM are sent to the caller to indicate that the call is awaiting the attention of an operator. When an operator accepts the call, the characters LONDON SWBD PXXX (where XXX is the switchboard position number) are sent to the caller, who is then in communication with the operator. The required number is transmitted to the operator who completes the connexion. By operating the switchboard ANSWER-BACK key in conjunction with the SEND CALL and SEND ANSWER keys, the operator causes the answer-back codes of the calling and called teleprinters to be exchanged, and the call proceeds as described in part (*a*).

(*b*) (*i*) Phonogram working is a system whereby a telegram can be dictated from a subscriber's telephone or public call-office to an operator at a central office. A special dialling code is used to gain access to a Phonogram position, causing a lamp to glow. The operator answers the call and types the dictated message on a telegram form. The form is taken by hand or conveyor belt to a transmitting position. The transmitting operator dials the code for the distant telegraph office over the teleprinter automatic switching system (TASS) and transmits the message by teleprinter. The message can be delivered by hand, by Printergram (using a subscriber's Telex machine), or by telephone if the recipient is a subscriber.

(*ii*) Gentex is the name given to the automatic switching system used for the transmission of telegrams between European countries. Telegrams are handled by dialling the distant terminal in a manner similar to that for the TASS. The network avoids costly and time-wasting retransmissions. Incoming traffic is routed over international Telex circuits to tape teleprinters; outgoing traffic uses the international Telex exchange in London but is segregated from Telex traffic to enable the correct charges to be applied.

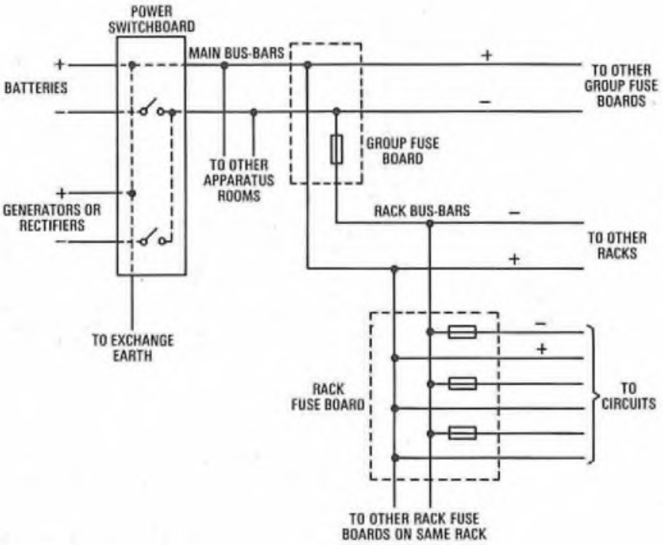
*Q 8 In an automatic Telex exchange,*

*(a) what power supplies are provided,*
*(b) how are they distributed,*
*(c) what arrangements are made in case of mains failure, and*
*(d) what protective devices are provided in the power-distribution system?*

A 8 (*a*) The power supplies provided in a Telex exchange are

(*i*) ±80 V d.c. for telegraph signalling,
(*ii*) −50 V d.c. for relay and selector operation,
(*iii*) a.c. mains for power units and charging batteries (through suitable transformers and rectifiers), and
(*iv*) 6·3 V a.c. for tube heaters.

(*b*) The sketch shows the distribution of the −50 V supply. The arrangements for the ±80 V supplies are similar.



(*c*) The power required by an exchange is normally provided by a mains-operated rectifier set, or sets, with a battery connected in parallel. If the a.c. mains supply fails, the battery will supply the exchange for up to 24 h. For medium and large exchanges, stand-by rectifier sets are provided as a precaution against failure of a set. Modern practice is to install diesel generators at large exchanges to provide a reserve power supply for up to 5 d. The generators are automatically started when sensing equipment detects failure of the mains and, as the generators can supply all the requirements of the exchange, the battery's capacity is limited to 1 h at peak loading. When the mains supply is restored, the generator automatically stops and returns to its stand-by mode.

(*d*) The protective devices in the power-distribution system are shown in the sketch.

*Q 9 (a) Briefly describe the procedure for dealing with a fault reported by a Telex subscriber.*

*(b) List 6 facilities provided by a Telex test-desk.*

*(c) Explain, with the aid of a diagram, how one of the tests available is made.*

A 9 (*a*) A subscriber normally reports a Telex fault by telephone, either via an operator or directly to the maintenance control. The subscriber's name and Telex number are noted, and the nature of the complaint is entered on the subscriber's fault card; an entry is also made in the fault register. The testing officer intercepts the subscriber's circuit at the engineering control-board and makes tests to determine whether the fault is in the exchange, on the subscriber's line or in the terminal equipment. Details of a line fault are passed to the voice-frequency transmission terminal or the appropriate telephone exchange. Details of subscribers' apparatus faults are passed to the repair centre, where a maintenance officer is detailed to visit the subscriber. Exchange faults are passed to the exchange maintenance staff. In all cases, numbered dockets are used, or reference numbers are given, so that a check can be kept on the progress and completion of the work. When the fault is cleared, the subscriber is informed and entries are made on the fault card and register. In the case of special faults, that is, frequent faults or those of long duration, more exhaustive tests are made or a special investigation is ordered. All Telex subscribers are entitled to attention at any hour of the day.

(*b*) For completeness, 9 facilities provided by the test-desk are listed. The facilities are to

(*i*) measure the conductor and insulation resistances of a line, and check for foreign potentials and earth potential,

(*ii*) measure line currents and voltages on a centre-zero moving-coil meter,

(*iii*) transmit a test message to enable the margin of a teleprinter to be tested,

(*iv*) measure the distortion on a circuit by the use of a telegraph-distortion measuring set,

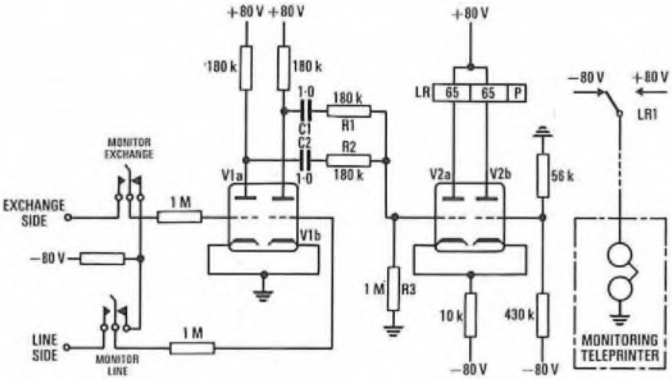
(*v*) measure the starting time and speed of a teleprinter,

(*vi*) measure the speed and ratio of a subscriber's dial,

(*vii*) monitor the SEND and RECEIVE wires of a circuit by a high-impedance tube-operated circuit,

(*viii*) communicate by telephone with a maintenance officer over a physical circuit under test, and

(*ix*) make calls to check the operation of distant equipment.



(*c*) The sketch shows the high-impedance tube-operated monitoring circuit fitted to a Telex test-desk. The telegraph circuit SEND or RECEIVE wire is tapped without interrupting the circuit. The exchange side of the circuit is connected to the grid of tube V1a through a 1 MΩ resistor. This circuit thus offers a high impedance to the line and draws minimum current. The line side of the circuit is similarly connected to the grid of tube V1b.

When both grids of tube V1 are at negative potential, the anode potentials are +80 V. The earth potential applied to the grid of tube V2a causes it to conduct. As the grid of tube V2b is at negative potential, tube V2b is non-conducting and relay LR is operated to transmit −80 V to the monitoring teleprinter, so that the latter is at rest.

Assuming the MONITOR LINE key to be operated, when positive potential appears on the line, tube V1b conducts and its anode potential falls to about +5 V. The change in potential transferred across capacitor C1 causes the potential of the grid of tube V2a to become negative, and tube V2a ceases to conduct. The common cathode potential falls and, thus, tube V2b conducts. Relay LR is therefore operated to transmit +80 V to the monitoring teleprinter. The time constant of the interstage coupling circuit is very long compared with the length of a signal element, so that the grid of tube V2a normally remains negative until the next negative potential appears on the line.

When the next negative line potential is received, the anode potential of tube V1b rises to +80 V. This change is transferred across capacitor C1 to restore the grid of tube V2a to approximately earth potential. Tube V2 continues to respond faithfully to line signals because the voltage change that occurs across the common cathode resistor when tube V2a conducts causes tube V2b to become non-conducting.

If the monitored line returns to positive potential for a long period then, although tube V2a initially cuts off, the long time constant of the coupling circuit ensures that the grid of tube V2a gradually returns to earth potential, so that relay LR eventually transmits −80 V to restore the monitoring teleprinter to rest.

If the exchange side is to be monitored, the MONITOR EXCHANGE key is operated, and monitoring takes place via tube V1a, capacitor C2 and resistor R2.

*Q* **10** *A mains-operated power unit is provided at a subscriber's teleprinter station.*

(*a*) *Explain the function of*

(*i*) *the transformer,*

(*ii*) *the rectifier,*

(*iii*) *the reservoir capacitor, and*

(*iv*) *the smoothing choke.*

(*b*) *Draw a circuit showing how these items can be connected to give* ±*80 V signalling supplies.*

**A 10** See A10, Telegraphy B, 1972, *Supplement*, Vol. 66, p. 30, July 1973.

Published by *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG, and
printed in Great Britain at the Gresham Press by Unwin Brothers Limited, Old Woking, Surrey.