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CONTENTS

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THE BRITISH POST OFFICE SPEAKING CLOCK MARK II

R. L. SMITH.*

Introduction

The first part of this article, by A. J. Forty and F. A. Milne of the British Post Office, published in the June 1954 issue of the Journal, dealt with the design and performance of the Speaking Clock Mark II. This, the second and final part, deals with the general layout of the installation, its manufacture, testing and packing for export.

General Layout of the Equipment

As stated previously, each installation comprises two complete clocks together with common equipment and auxiliary power supply. Each clock consists of an Announcing Machine, which is mainly mechanical, together with drive oscillators, amplifiers and correcting apparatus which are almost entirely electronic. This electronic equipment, plus the common equipment (which is also electronic), is mounted on ten seven-foot high racks. Because of association of function, these racks are bolted together in pairs and electrically interconnected to form five units before leaving the factory. The various items comprising the complete installation at Melbourne (with a similar set at Sydney) are therefore:—

(a) Two Announcing Machines.

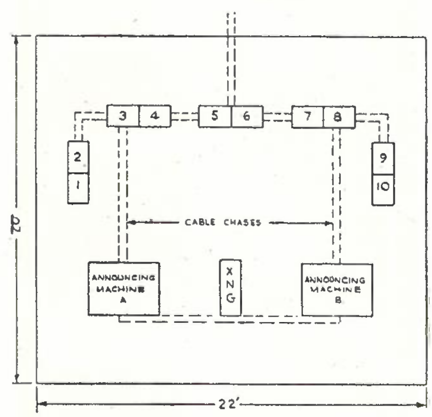
(b) Five pairs of 7ft. racks carrying electronic equipment.

(c) Two Time Signal Generators (mounted, with control panel, on one table).

(d) Auxiliary power supply and control panel.

Fig. 1 shows how the first three of these items are arranged in the Clock Room. Item (d) is not shown because it is housed in a separate room. The five pairs of racks of electronic equipment are arranged in a U-formation with the Announcing Machines and Time Signal Generators closing the open end of the 'U'. The racks are equipped with panels on the front only (except for some of the power supply units) and the fronts face inwards, as also do those of the Announcing Machines and Time Signal Generators. Thus a maintenance engineer standing in the middle of this square formation can observe with ease the various meters, switches, indicator lamps, etc., on the racks and also the operation of the mechanical equipment without moving from his central position.

It will be seen from Fig. 1 that Oscillators A and B are mounted on Racks Nos. 1 and 10 and that these are at the ends of the 'U'. Normally Oscillator A drives Clock A (carried on Racks 3 and 4) while Oscillator B drives Clock B (carried on Racks 7 and 8). Oscillator C (Rack 2) is normally the spare and may be used to drive either clock if Oscillators A or B should fail. The change-over is accomplished by plugs and sockets on Rack No. 9 which also carries the Monitor and Alarm equipment for all three oscillators. The two racks of Common Equipment (Nos. 5 and 6) are conveniently placed between Clocks A and B. It will be seen also that Announcing Machine A is placed opposite the electronic equipment of Clock A while Announcing Machine B is opposite that of Clock B, the Time Signal Generators being between the two Announcing Machines. The engineer starting up or making adjustments to either Announcing Machine is therefore able, merely by turning his head, to observe the results on the indicating instruments on the appropriate racks. He may also listen to the announcement on loud-speakers which are mounted at the top of racks Nos. 1 and 10 and which can be switched independently to monitor various points in the system. The whole makes a pleasingly symmetrical arrangement of the two clocks about the common equipment.



RACK No.	UNIT
1	OSCILLATOR A
2	OSCILLATOR C
3, 4	CLOCK A
5, 6	COMMON EQUIPMENT
7, 8	CLOCK B
9	COMMON OSCILLATOR EQUIPMENT
10	OSCILLATOR B
XNG	TIME SIGNAL GENERATORS

Fig. 1.—Layout of Installation in Clock Room.

It will be noticed that spaces have been left between the pairs of racks and also that there is what may appear to be waste space between the racks and the machines. The reasons for this are threefold. Firstly, it adds to ease of maintenance; secondly, it minimizes fire risk and thirdly, it allows a reasonable number of people to see the installation at one time. The latter reason is important since the equipment obviously has exhibition value, being probably the most accurate Speaking Clock Installation in the world.

Arrangement of the panels on the racks: Certain general principles have been adopted in arranging the panels on the racks. These are:—

(a) No panels carrying controls or indicating instruments are mounted on the rear of the racks. In fact, only power supply panels are thus mounted, and this has been done only on racks where the front is already fully occupied.

(b) All power supplies (230 V a.c. and 50 V d.c.) enter the racks via Mains and Battery Distribution Panels which are located at the bottom of the racks, there being one such panel for each pair of racks. These panels carry switches, fuses and neon indicator lamps for the mains input to the individual power units together with rack isolating switches. They also carry fuses

*Line Transmission Development Department, Telephone Manufacturing Co. Ltd., St. Mary Cray, Kent, England.

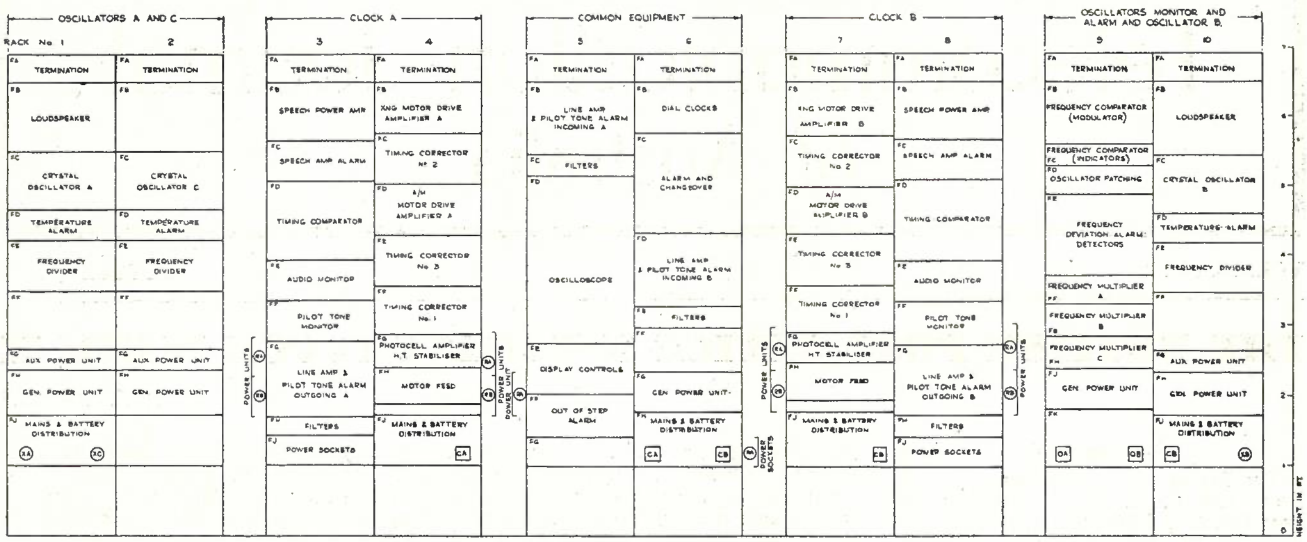


Fig. 2.—Layout of Panels on Racks.

for the 50 V d.c. supplies to the various panels and the Announcing Machines and each mounts a 50 V fuse alarm lamp.

(c) All 230V a.c. wiring has been run in conduit to reduce fire risk.

(d) All other electrical connections to the racks are made via Termination Panels which are located at the tops of the racks. These panels carry tag blocks for the d.c. and audio frequencies and co-axial connectors where radio frequencies are involved. One Termination Panel is provided per rack.

(e) As far as possible, panels carrying indicating instruments have been grouped at eye level. No panel is closer to floor level than one foot.

Fig. 2 shows the layout of the panels on all ten racks.

The Oscilloscope Panel is perhaps worthy of special mention since it is basically different from the other panels. It consists only of a metal hood, sprayed matt black inside and fitted with doors at the front. There is an aperture at the rear of the hood through which the front of a standard Cossor double beam oscilloscope projects. For normal use the oscilloscope, which is mounted on a trolley, is connected to the clock installation by a Jones type plug. By means of controls on the panel situated immediately below it, simultaneous displays of two wave forms at various points in the system or the progress of a timing correction may be followed. If the oscilloscope is required for fault tracing in other parts of the equipment, it may be easily unplugged from the rack, wheeled out of its hood and brought round to the front of the equipment for use in the normal manner.

Fig. 3 shows the two racks of Common Equipment with the oscilloscope in position but with the doors removed. The covers of the other panels have also been removed.

Fig. 4 shows the two racks of Clock B with the cover in position.

Panel Design: The principle of ease of maintenance has also been dominant in the design of the individual panels. To this end, care has been taken that no component is obscured by another component and all soldering tags have been made easily accessible for the measurement of voltages, resistances, etc. It became obvious, when designing some of the panels, that the meter and its associated wafer switch made compliance with this principle extremely difficult without considerable waste of panel space. The difficulty was solved by hingeing the switch and meter sub-panel so that it could be swung out of the way for maintenance purposes. Fig. 5 illustrates this in the case of the Timing Comparator Panel.

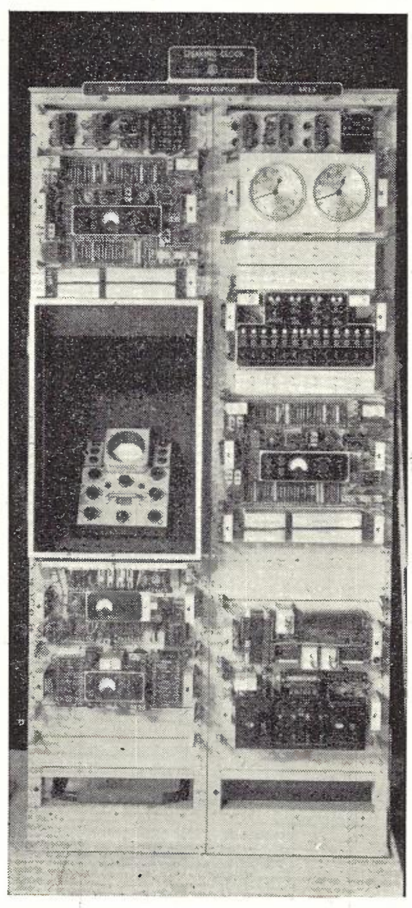


Fig. 3.—Common Equipment Racks (Panel covers off).

In general, electrical connections to panels have been made via soldering tags carried on blocks located one at each end of the panel, the left hand block being used for signal wiring and the right hand block for power wiring. A standard arrangement was used so that on any panel the same supplies would always be found on the same tags. Thus, H.T. always appeared on tag 1 with the negative on tag 3. 6.3 V a.c. for valve heaters always appeared on tags 4 and 6, 50 V negative on tag 11 and so on. For the wiring of the panels 22 S.W.G. tinned copper wire covered with insulating sleeving has been used almost throughout. By using both striped and plain coloured sleeving a total of seventeen different colours became available and these were used to designate the functions of the various leads. For example, input leads were green, grid leads white, anode leads yellow, H.T. red, earth black and so on. The use of this colour coding was of considerable assistance during the testing of the panels and it is believed that it will be very helpful during maintenance and fault finding.

All components were chosen to withstand the tropical conditions likely to be encountered on the sea voyage to Australia, even though precautions to minimize the effects of these were taken in the packing, as described later in the article.

Features of Manufacture and Testing

When manufacture of the Melbourne installation was begun by the Telephone Manufacturing Company, the design of the whole equipment (which was the responsibility of the British Post Office) was not complete. As a consequence, it was necessary to alter or remake certain parts that had already been manufactured in order for them to work satisfactorily with parts subsequently designed. It also became obvious, as the system was built up, that additional facilities were desirable and this, of course, demanded the design and manufacture of extra parts. All this involved close co-operation between the B.P.O. and the T.M.C. and to this end two of the Company's engineers and two of its draughtsmen spent several months at the British Post Office Research Station before and during the early stages of manufacture, while two Post Office engineers spent some months on T.M.C. premises during the testing stage. The situation was complicated by the fact that the mechanical part of the installation was made in one T.M.C. factory, while the electronic part was made in another. The auxiliary power supply was made by an entirely separate contractor and the Time Signal Generators by yet a third contractor.

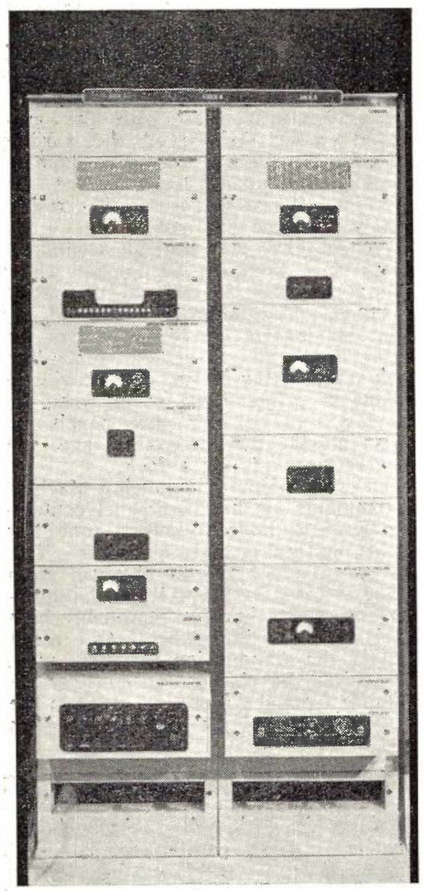


Fig. 4.—Clock B electronic equipment racks.

For testing purposes it was essential to bring all these items together in one place and to interconnect them electrically. The equipment, although rather elaborate in conception, is straightforward in design and based on well established principles. It did, however, call for a few manufacturing and testing techniques and facilities not normally available in a company manufacturing the more conventional items of telecommunications equipment. Some of these will now be mentioned.

The Drive Oscillators: These were expected to have, and in fact did have, a stability of 1 part in 10^8 per day once the crystals had settled down. In order to check this it was necessary to have a 100 kc/s reference frequency which had a day to day stability of at least one part in 10^9 and whose daily drift was constant and predictable. No such stable frequency was available when manufacture was begun and the first job was to provide one. This was achieved by building an oscillator identical to the clock oscillators but using a clamped GT cut crystal and installing this in a vibration-free room, the temperature of which was thermostatically controlled at 30° ± 1°C. Standby power supplies were provided for this oscillator and these came into action immediately and automatically if the mains failed. The oscillator was thus run continuously; after six months its drift rate had dropped to a few parts in 10^9 per day and after one year's running to 1 part in 10^9. It is of interest to note that after two years' continuous ruunning the daily drift rate was 8 parts in 10^{10}. This sub-standard oscillator was checked daily against standard frequency transmissions received by radio from Rugby and provided by the National Physical Laboratory. By this means not only could the day to day stability of the clock drive oscillators be checked under ordinary room conditions but their performance at extremes of temperature and supply voltage could also be assessed.

The Frequency Comparator Panels: As stated earlier three oscillators are provided, the frequencies of which are continuously compared with each other and the total differences displayed on a scale-of-ten indicator similar to a kilowatt-hour meter. This meter is driven by a small three-phase motor operating at the beat frequency of a pair of oscillators. It was necessary to test these motors (which were a purchased item) before a pair of oscillators was available. This was accomplished by using one oscillator and a delay line giving known amounts of delay in multiples of 30°. The direct 100 kc/s signal and the delayed signal were then fed to a modulator and the output of this fed to the motor via a phase splitting network. By changing the taps on the delay line, rotations in 30° steps could be obtained.

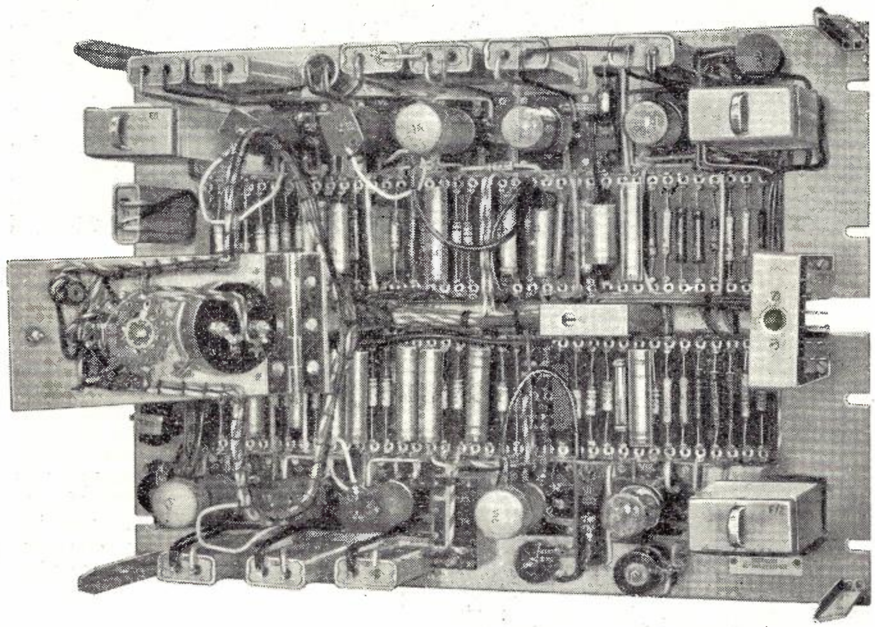


Fig. 5.—Timing Comparator Panel showing hinged meter sub-panel swung clear.

The Announcing Machines: The manufacture of the units comprising the Announcing Machines presented a number of individual machining problems involving extreme limits of accuracy. The bedplate upon which the various units are mounted consists of a very stable aluminium alloy casting of thick section, strongly webbed on the underside and weighing nearly 2 cwt. The top surface measures 46 in. by 30 in. and has been machined so precisely that a feeler gauge 0.002 in. thick will not pass under a straight-edge placed anywhere upon it. The four cams which control the positions of the photocell/lens systems in relation to the sound tracks on the speech discs are made of Nitralloy steel and these, like the feed ratchets on the camshafts, are hardened

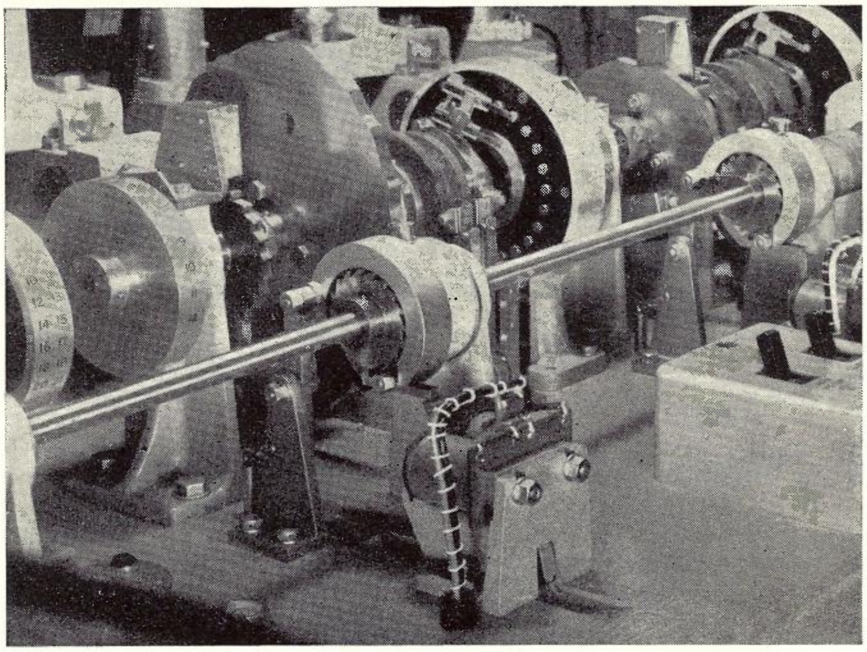


Fig. 6.—Hours and seconds carriage shift mechanism.

to a degree approaching that of sapphire. The essential steps cut round the edges upon which the follower rollers bear for operating the carriage shift mechanisms are highly burnished and finished within ±0.001 in. of the theoretical radius.

Fig. 6 shows two of these cams together with the pawl and ratchet mechanisms and the electromagnet for operating the clutch.

The 1 in. diameter shaft carrying the speech discs is made of nickel chromium steel and finish-ground within ± 0.0001 in. of nominal size. The motor shaft turns at a speed of 166⅔ revolutions per minute and a two-stage reduction gear produces the final output speed of 30 r.p.m. at the speech disc shaft. Precision cut helical gears with finely lapped teeth are employed for this purpose. The accuracy embodied in these gears is of a high order as is shown by the following figures.

Backlash between any intermeshing pair—0.0008 in./0.0014 in.

Pitch circle concentricity: Variation ± 0.0003 in./± 0.0012 in.

Pitch error: Maximum deviation
on 36 tooth pinion 0.0001 in.
on 60 tooth gear 0.0002 in.
on 120 tooth gear 0.0004 in.

In order to ensure the smoothest possible transmission of power from the main motor shaft to the speech disc shaft two devices are incorporated. The first of these is a torsion bar which links these two shafts and which, by virtue of its mechanical compliance, smooths out the 50 c/s component of the motor torque. The second is a fluid flywheel which is mounted on the motor shaft. This prevents motor hunting and also effectively damps any mechanical resonance there may be in the torsion bar/disc shaft combination and which might be excited by remanent gear irregularities. Frictional losses are minimized by the use of specially selected ball races throughout the motor and gearbox unit, the fluid flywheel and the disc shaft pedestals. The highest degree of precision on spindle diameters and bored holes for housing the bearings was demanded. Machining limits of the order of 0.0003 in. had to be specified in these instances, calling for very careful selection and fitting in the assembly stages.

The method of checking the rotational stability of the system is perhaps interesting. One of the speech discs was replaced by a disc carrying a 1 kc/s sound track and the output obtained from this, when scanned by the optical system, was displayed on one beam of an oscilloscope. On the other beam was displayed a 1 kc/s trace obtained from the same frequency divider as was driving the motor. Any rotational irregularities were thus shown up and could be measured easily. With careful attention to the points mentioned above these were reduced to less than ± 1 millisecond.

The satin chrome finish used on all external brass and steel components (except the shafts) presents a pleasing appearance in contrast with the grey stoved enamel surface of the various cast parts. Both processes required careful preliminary treatment of the machined items to ensure the results achieved on the final job.

A steel cover with four glass windows keeps dust from the equipment whilst giving an adequate view of the whole machine. Ventilation is provided by four openings in the lower part of the cover and a louvre at the top. The lower ventilating holes also provide a means of gripping the cover when removing it. The four glass panels are also individually removable and are secured normally by a lock.

The base of the Announcing Machine also mounts an amplifier panel containing seven cathode followers (one for each photocell) and a mixer. This ensures that the signals obtained from the glass discs are fed to the main amplifiers on the racks at a reasonably high level and a low impedance. As a result of this, the Announcing Machines may, if required, be placed at a considerable distance from the racks. A door in the left hand end of the main cover gives

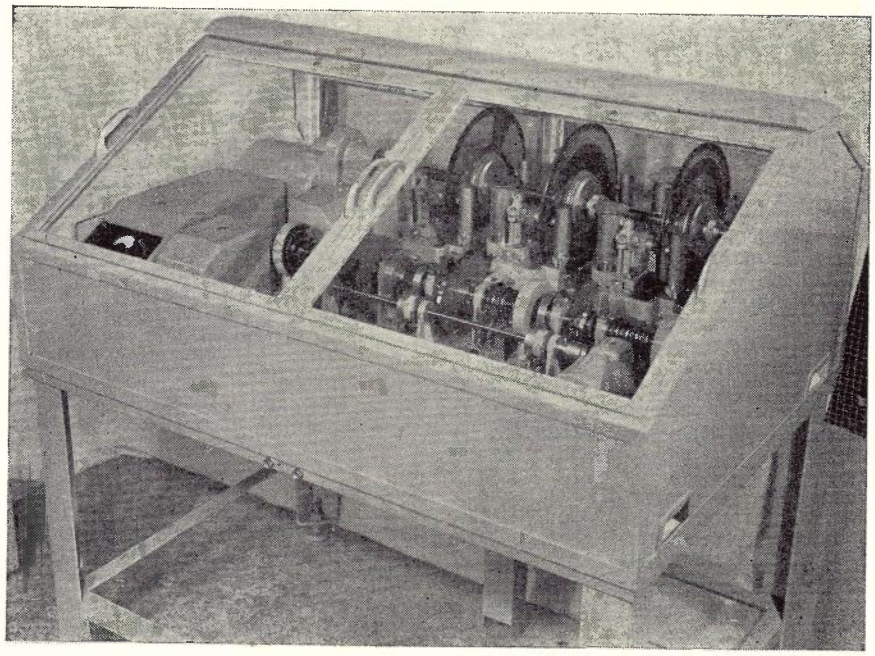


Fig. 7.—Complete Announcing Machine with cover in position.

access to the controls of this panel. Fig. 7 shows a complete Announcing Machine with its cover in position. The cathode follower panel may be seen at the left of the illustration.

Glass Disc Records: The manufacture of these, which was undertaken by the British Post Office, will not be described here as an account of the process has already been given in the Post Office Electrical Engineers' Journal for April 1954 and in the Telecommunication Journal of Australia for June, 1954.

Fig. 8 shows the hours and seconds discs mounted on the shaft, together with the exciter lamps and photocells.

Performance Testing: In order to assess the performance of the clock and to make sure that the correcting equipment operated satisfactorily over a period of weeks, time signals were received over a telephone line from the Royal Observatory at Abinger, Surrey, England, and these were used for the daily correction of the clock during its trial run. Tests of the correcting mechanism when operated by signals received over a 400 mile carrier line were also made.

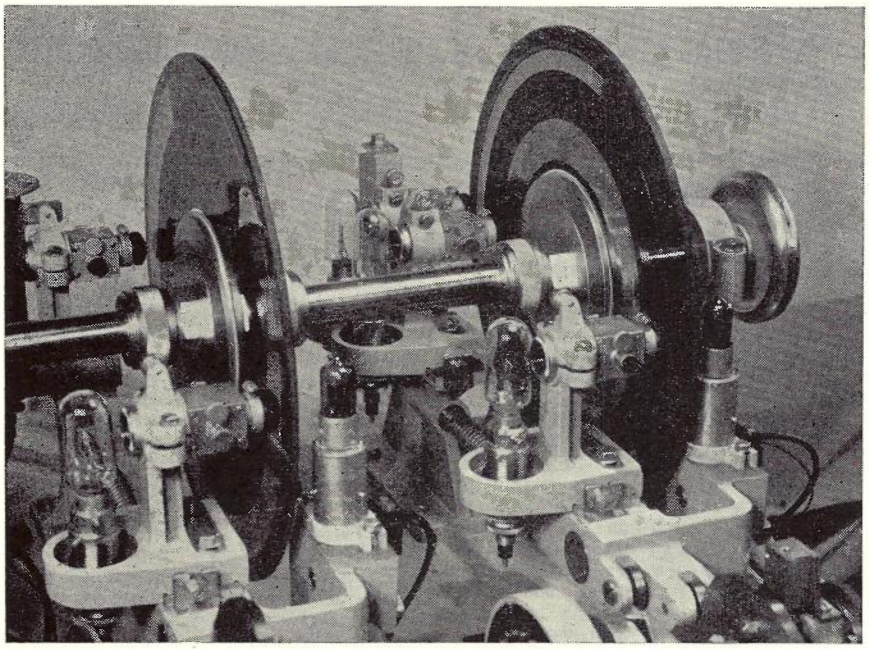


Fig. 8.—Two of the glass disc records with exciter lamps and photocells.

Packing for Export

The method of packing depended upon three main considerations:—

(a) The delicacy of certain parts of the equipment.
(b) The deleterious effects of moisture.
(c) The effects of vibration on adjusted components.

An additional reason for extra care in packing was that most of the components had been individually manufactured, and that spares would not be immediately available but were to be shipped later. It was also important to preserve the fine finish of the equipment.

It was therefore decided to adopt the following principles in planning the packing:—

(a) The case or crate should securely grip the article to be packed, as illustrated in Fig. 9. This case would then be "floated" on a suitable resilient material, such as rubber or wood wool, within an outer container or containers, dependent upon the fragility of the item.
(b) A moisture barrier should be introduced between the article and the inner case.
(c) The outer case should be protected from weather and sea water by a moisture-proof lining. This is important in spite of the inner moisture barrier since water entering the outer case could damage the resilient packing material.

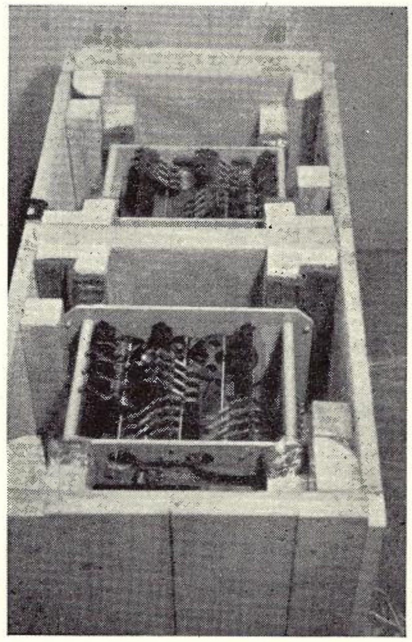


Fig. 9.—Time Signal Generators packed in inner case.

The packing of one particular item—the Time Signal Generators—will now be described in detail to illustrate the above considerations and is typical of the 42 packages which made up the complete shipment.

The Clock Installation: Fig. 9 illustrates the Time Signal Generators in their close-fitting case, which was lined throughout with the moisture-insulating material. This material was creped kraft interleaved with bitumen, having all joints sealed with "Bostik". The machines were held firmly in position by felt-faced wood blocks. Before sealing this box, a suitable quantity of silica gel in bags was put in to absorb moisture from the air in the box.

After fixing the lid, the box was wrapped in metal foil sandwiched between two kraft sheets, one of which was coated with polythene. The sheets were then sealed by fusing the polythene with a hot iron to form an air-tight joint.

The second case, the overall dimensions of which were 3 in. greater than those of the first, was also lined with the moisture-insulating material and sealed with "Bostik". It may be pointed out here that creped kraft is elastic and therefore does not split if the case becomes distorted under stress.

The inner case was then "floated" within the outer by means of blocks

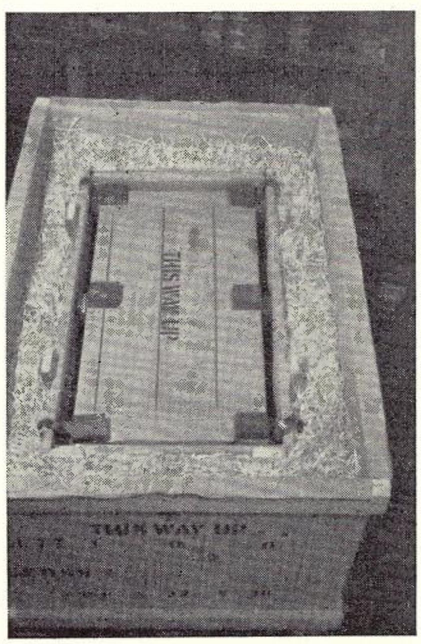


Fig. 10.—Inner case "floating" within two outer cases.

composed of a mixture of rubber and fibre. This allowed ample resilience without loss of rigidity in a plane at right-angles.

The third and final packing case was 6 in. larger than the second in all dimensions. This was lined and sealed as the others and case No. 2 "floated" inside it, this time by means of wood wool, as shown in Fig. 10.

The lids of all cases were lined with creped kraft moisture-insulating material with sufficient overlap to enable them to be sealed with "Bostik" to the main case lining when closed.

The Quartz Crystals. Owing to the extreme susceptibility of these crystals to mechanical shock, they were flown to Australia. The crystals were mounted in the double-walled ovens in which they are housed in the oscillators and these ovens were carried in a special container lined with thick sponge rubber, two ovens being accommodated in one carrying box. In spite of these precautions, of the ten crystals thus sent, one was damaged in transit.

Spare Parts: All spare parts were individually packed in such a way that they would remain in good condition over a long period. Bearings were oiled before wrapping and other items were protected by corrugated cardboard. Each part was then closely wrapped in waxed paper and placed in a transparent polythene bag. An identification label placed therein was clearly visible through the polythene. Air was extracted from the bags, which were then heat-sealed to make them air-tight. This process eliminated the danger of sealing the item in a moist atmosphere. The bags were then packed in wooden cases for shipment.

This method of packing enables a storekeeper to identify each component by its appearance and by its label without opening the protective wrapping.

Conclusion: It is as yet too early to say whether the method of packing the spare parts has achieved its objects. It is known, however, that both installations arrived in Australia in excellent condition and are now operating satisfactorily.

THE TRANSISTOR — A SURVEY OF ITS PHYSICAL AND ELECTRICAL PROPERTIES

G. FLATAU, F.M.T.C.

Introduction: Since the first announcement of the transistor by the Bell Telephone Laboratories in July 1948 the device has been subject to intense theoretical and developmental research. The advantages which transistors offer for miniaturization, power economy and robustness make it certain that they will be used increasingly in telecommunications equipment in the future. Consequently, it has been deemed advisable to publish this survey as a medium to acquaint readers with the basic physical and electrical principles of transistor devices.

Historical: The first announcement about the transistor was made in July 1948, in a paper by Bardeen and Brattain of the Bell Laboratories (1). It was an outcome of investigations into the properties of semi-conductors and their application as rectifiers, which had received great impetus during the war when germanium and silicon diodes found wide application in the field of radio location.

The first transistor developed was of the point contact type, which was in many ways a close kin to the crystal rectifier of the early years of radio. In 1949, Shockley advanced the theory of the junction transistor, which was soon turned into reality (2). Since then, various types have been proposed and sometimes turned into actual models, so that today many varieties of transistors are in commercial production. Whilst some of the earlier claims, that the transistor would almost completely replace the vacuum tube, now appear highly problematical, there is no doubt that transistors can play a vital part in future electronic design, especially where small physical size, minute power consumption and small heat dissipation are of importance. At the moment there are still limitations with regard to cost, reproducibility, frequency response and noise, but with a large number of manufacturers engaged in commercial production, most of these factors are being actively studied, and considerable improvements have already been achieved. It seems only fair not to expect one or the other type of transistor to provide a universal solution to all design criteria, but rather to regard the various types as being suitable to varying applications, just as a multitude of types of vacuum, gas and photo tubes are necessary to fulfil the demands of present day design.

Fundamentals of Semi-Conductor Physics: Generally speaking a semi-conductor is one whose resistivity lies intermediate between that of a conductor and insulator. On the one hand there are conductors such as for instance copper, with a resistivity of 1.75×10^{-6} ohm-cm. and at the other end of the scale are insulators such as mica, resistivity $= 10^{16}$ ohm-cm. The semi-conductors of interest have resistivities of the order of 10^{-2} to 10^{4} ohm-cm. at room temperature, for instance high purity germanium has a resistivity of 56 ohm-cm. at 300 degree Kelvin (27° C). The semiconductors met in the field of electrical engineering such as germanium, silicon, selenium and copper oxide, etc., are all electronic rather than ionic conductors, that is, the conduction process proceeds by the gain or loss of electrons, whilst the actual constituent atoms remain in fixed positions.

The elements of main interest as basic building stones for transistors are the so-called transition elements of group IV of the periodic table, in particular germanium and silicon, although some success has been reported with such compounds as lead sulphide and mixed alloy compounds such as indium antimonide or arsenide.

Although this paper will, in general, deal with germanium as the basic material, it must be remembered that it will apply also to silicon and even to carbon (at very high temperatures) and tin (at sub-zero temperatures), with only the numerical values varying. Germanium forms crystals of the diamond type structure in which each atom has four equi-distant neighbours, which are themselves equi-distant. The atom of germanium consists of a positively charged nucleus of charge $+ Ze$ (where Z is the atomic number and e the electronic charge) surrounded by $(Z - 4)$ tightly bound electrons and 4 more loosely bound valence electrons. Only the valence electrons are available to enter into combination with neighbouring atoms, or assist in conduction. In the diamond type lattice each atom will join up with four neighbours, by each contributing one electron to form a co-valent bond. See Fig. 1 (a) for a two-dimensional representation.

The reason why such a configuration is the most stable is explained by quantum mechanics and will not be further discussed here. A crystal as shown in Fig. 1 (a) would, of course, be a perfect insulator as all the electrons are bound in their co-valent bonds, and none are available for conduction purposes. It is a known fact that diamond which approximates such a perfect crystal at ordinary temperatures, is an exceedingly good insulator, and in fact, germanium and silicon at temperatures near the absolute zero are also perfect insulators. At ordinary temperatures there are as a rule several conditions which tend to destroy the perfect symmetry of the germanium lattice, and it is due to these slight imperfections in an otherwise nearly perfect crystal that transistor and rectifier action is made possible. At room temperature, the atoms in their positions in the crystal are not perfectly rigid, but have certain thermal vibrations, and it is possible that some of these vibrations can become large enough to break a co-valent bond, and thus release one or both of the electrons for conduction purposes. Incident light, on striking a co-valent bond, can, providing it is above a certain minimum frequency, eject an electron.

The imperfections of most interest, however, are atomic in nature, that is atoms of elements, other than the bulk material, which manage to get themselves included in the crystal lattice. If one considers the case where one of the germanium atoms in the lattice gets replaced by an atom of an element which has five valency electrons, such as arsenic or antimony, it being assumed that the atomic dimensions of the substituted atoms are such as not to deform the lattice structure, there will now be an excess electron in the crystal which cannot find a place in the co-valent bonds. See Fig. 1 (b).

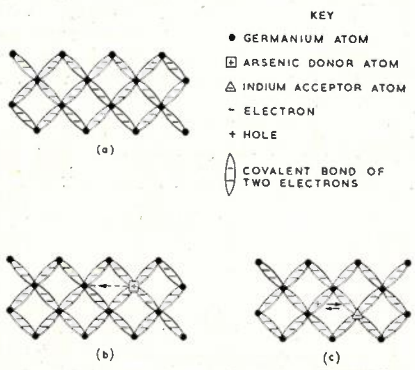


Fig. 1.—Pure, n-type and p-type Germanium crystal lattice.

Although the arsenic atom has as many positive charges on its nucleus as there are negatively charged electrons surrounding it, the excess electron will not be tightly bound to the arsenic nucleus, but will rather be able to drift through the crystal lattice. The reason for this is that due to the high dielectric constant of germanium (≈ 16), the positive charge developed on the arsenic nucleus is effectively shielded and hence the nucleus has only about 1/16 of its normal attraction for the wandering electron, so that it requires only about 0.01 electron Volt (eV) at room temperature to remove the excess electron which is now free to wander through the crystal, and in the presence of an electric field will contribute to the conduction. Elements, such as arsenic, which "donate" an excess electron are called donors, and since the conduction will be by negative charges, the germanium is called n-type. In view of the close spacing of the charged atomic nuclei in the crystal lattice, it might seem surprising that the electron can move around randomly, very much the same as in free space, but the solution is provided by wave mechanical theory which states that a wave (i.e., an electron) can be propagated through a lossless structure of perfect periodicity without attenuation. This is reminiscent of the theory of iterated filters. In general, an excess electron in a germanium crystal at room temperature will travel about 10^{-5} cm before colliding with an atom and will collide about 10^{12} times per second.

If, however, the substituted atom in the germanium lattice had been of an element such as gallium or indium, which has only three valency electrons, one of the covalent bonds would remain uncompleted. See Fig. 1 (c). It can be seen that a localised positive charge, equal to one electronic unit, has been created. It is possible for an electron from a neighbouring bond to jump into the vacancy, and thus in effect the positive charge has moved to the point of origin of the electron which jumped. The positive charge is called a hole, and it is able to leave the vicinity of the now negatively charged parent nucleus for the same reasons that the excess electron could leave the donor atom. The hole is thus available for conduction purposes, and as this is conduction by positive charges, the material is now p-type. Atoms of elements which "accept" an electron in order to complete their covalent bonding are called acceptor atoms. Although a hole does not represent a real particle, the concept of holes has a meaning in the mathematical sense, and surprisingly enough it is found that some parameters of hole behaviour are not the same, or simply the negative of those for electrons. The movement of a hole under an applied electric field will be opposite to that of an electron, its virtual mass about the same, but the velocity with which it drifts through the lattice is only about half of that of an electron.

From the above it can be seen that conduction in a semiconductor can proceed in two ways, conduction by electrons and conduction by holes, and furthermore the two processes can occur simultaneously. In general there will be both donor and acceptor impurities present in the crystal, and thus it is to be expected that some excess electrons and holes will re-combine, thus effectively cancelling out. Depending whether the donor or acceptor density is greater, the material will be either n or p type, and providing both densities are low and equal, the crystal will essentially behave like a pure, or intrinsic, germanium crystal.

Certain impurities of an unwanted nature occur in the crystal which will act as catalysts for recombination. These flaws are called "Deathnium" centres and are believed to be connected with the presence of copper and iron impurities and with grain boundaries. Deathnium centres will reduce the lifetime of the minority carriers, that is excess electrons in p-type germanium. Thus, whereas in normal circumstances these electrons would have a life of from 20 microseconds to 1 millisecond before recombining with a hole, deathnium centres might reduce the lifetime to below a microsecond. As will be shown later, this must be avoided under any circumstances to obtain transistor action and hence transistors are usually made of single crystals to overcome the deathnium effect at the grain boundaries.

The electron and hole density in a crystal are connected by a relationship which depends on the ambient temperature and the bulk material. For germanium at room temperature:—

$$np = n_i^2 = 5 \times 10^{26}/\text{cm}.$$

where n = electron density per cc.
p = hole density per cc.
n_i = intrinsic density per cc.

In a crystal of germanium with no field applied, the electrons and holes are moving in a purely random fashion with velocities which are only dependent on the temperature (about 10^7 cm/sec. at 300° K). They will collide with the thermally vibrating atoms, get scattered, but in general there will be no net motion of charge per unit time, before they finally recombine with a hole. If an electric field is applied, the charges will now have an average drift velocity $\bar{v}$, the direction being dependent on the polarities, and hence there will now be a motion of charge, that is a current will flow. For electric field strength up to about 1000 V/cm., an Ohm's law relationship holds between current density and applied voltage, given by:

$$I = \sigma E = ne\bar{v}_n + pe\bar{v}_p$$

hence $\sigma = neu_n + peu_p$
where σ = conductivity
e = electronic charge
$u = \bar{v}/E$ = mobility (average terminal velocity per unit field) and the subscripts n and p refer to electrons and holes.

The mobility for electrons in germanium is 3600 cm/sec/Volt/cm and for holes 1800 cm/sec/Volt/cm.

These values lead to a resistivity for intrinsic germanium ($n = p = n_i$) of about 56 ohm.cm. It can now be seen how the addition of impurities will lower the resistivity. Assume 1 part in 10^7 of donor impurities are added to intrinsic germanium, then, since germanium has about 4.5×10^{22} atoms/cc.

$$n = 4.5 \times 10^{22} \times 10^{-7} = 4.5 \times 10^{15}$$

$$p = \frac{n_i^2}{n} = 1.1 \times 10^{11}$$

and since n is much greater than p, the germanium will be n-type. Substituting for n, p, e, and u, one finds that the resistivity is now 0.38 ohm.cm.

Above field strengths of 1000 V/cm the Ohm's law relationship does not hold and the drift velocity will tend to a limiting value of about 10^7 cm/sec. and hence the current density will remain substantially constant, up to about 250,000 V/cm. where a breakdown mechanism leads to very high currents (Zener currents) with the possibility of permanent damage to the crystal.

Returning to the case where there is no field applied there is another kind of phenomena, termed diffusion, which is of great importance in transistor physics. Assume that by means such as a flash of light, a number of electron-hole pairs are created at a point in a crystal of say, n-type germanium. The holes will undergo their usual random motion, but apart from that there will be an effect to distribute those holes through the body of the crystal, which were in excess of equilibrium conditions at the zone of creation. This motion of charge carrier is called diffusion, and the latter always acts in such a way as to destroy a build up of charge concentration. The diffusion length L_p or L_n (for holes or electron) is defined as the distance to which the charges will diffuse before their density has fallen, due to recombination, by a factor $1/e$. Another factor already encountered, the lifetime of the carrier, is proportional to the square of the diffusion length, and hence again the need for single crystals in transistor physics is demonstrated. (See also Appendix I.)

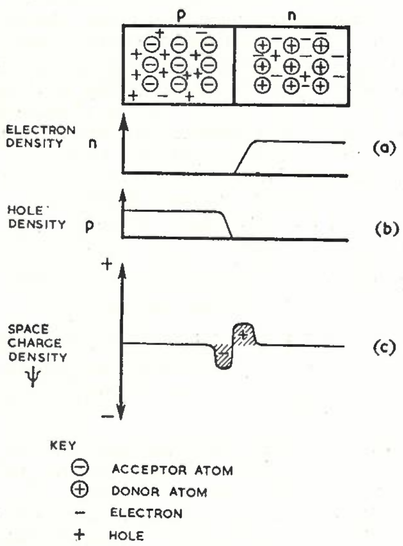


Fig. 2.—p-n junction.

Theory of p-n Junctions: It is possible to have a single crystal which contains both p and n-type regions, with a defined boundary between the two regions. Fig. 2 shows the general conditions of such a p-n junction, and in Fig. 2 (a) and (b) the electron and hole densities are plotted.

It can be seen that holes are mainly found in the p-region where they neutralise the space charge due to the acceptors, and similarly electrons are found mainly in the n-region, neutralising the donor space charge. To retain the equilibrium condition, there must be an electrostatic potential field set up, since the electrons will tend to diffuse to the p-region and the holes to the n-region, with a resulting net transfer of charge across the junction. The field will build up, with the n-region positive with respect to the p-region, to balance this diffuse flow, and equilibrium conditions will thus be maintained. A potential barrier is thus set up which ensures that the number of holes diffusing from the p-region to the n-region is equal to the number of holes thermally created in the n-region within one diffusion length of the junction, which flow to the p-region. The same balance conditions will apply for electrons, with the two directions reversed, and the net effect is to clear the immediate vicinity of the junction of electrons and holes, and a space charge dipole layer is created, which is usualy termed the depletion layer (Fig. 2(c)).

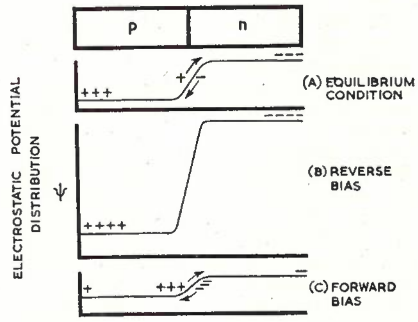


Fig. 3.—Potential distribution in p-n junction.

The equilibrium condition will be destroyed, if a potential is applied across the junction. If a reverse bias is applied, that is a positive voltage is applied to the n-region and a negative voltage to the p-region, the potential hill at the junction becomes steeper, and a lesser number of holes will be able to diffuse from p to n, whilst on the other hand the number of thermally created holes in the n-region sliding down the hill will be virtually unaffected (Fig. 3(b)). Thus the hole current from p to n has been reduced, and if the bias is made sufficiently negative, ceases altogether, whereas the thermal hole current from n to p remains unaltered.

In the case of a forward bias (Fig. 3(c)), where the p-region is now positive with respect to the n-region, the potential barrier is lowered allowing a greater hole current from p-region to n-region, whilst the thermal hole current from n to p is virtually unchanged. Thus with forward bias, the diffusion current is the dominant one.

A similar set of circumstances holds for electrons, and the voltage current characteristics of such a p-n junction is given by:

$$I = I_s \exp\left(\frac{eV}{kT} - 1\right)$$

where I_s = thermal saturation current of holes and electrons.
k = Boltzmann's constant
T = temperature in degree Kelvin
V = applied voltage

At room temperature $e/kT = 39/eV$ and hence the equation can be written approximately

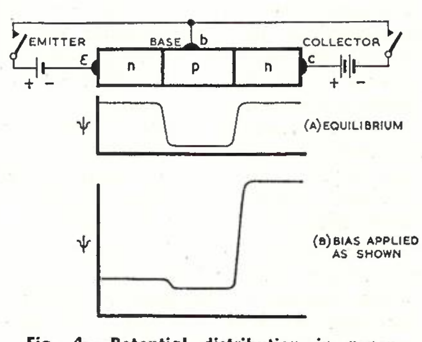


Fig. 4.—Potential distribution in n-p-n junctions.

$I = I_s \exp(39\,V)$ for V greater than .1 volt
$I = I_s$ for V less than -0.1 volt

The above rectification characteristic holds until the Zener breakdown voltage is reached at about 250,000 V/cm. (For proofs of some of the above formulae see Appendix II.)

Junction Transistors: A junction transistor consists of a single crystal "sandwich" which can be either pnp or npn. Ohmic contacts are made to each region, that is low resistance, non-rectifying contacts which have the property that they only inject majority carriers, that is a contact to an n-region will ensure that nearly all carriers entering or leaving are electrons (which are the majority carriers in n-region, see Fig. 2).

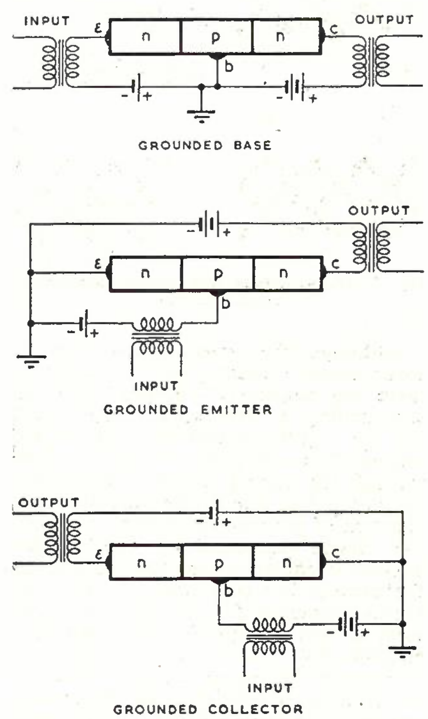


Fig. 5.—Possible connections.

In Fig. 4, the potential distribution for a npn junction is shown. In equilibrium the distribution is as shown in Fig. 4(a). If now the left hand junction is biased in the forward direction and the right hand junction in the reverse direction, the potential distribution of Fig. 4(b) results. A current will now flow across the left hand junction, and the electron component of this current flows from the n-region to the p-region, where they will recombine on an average within one diffusion length from the junction. At the same time the current across the right hand junction will be the saturation current only, since this junction is biased in reverse. If the width of the p-region is now made much smaller than one diffusion length, electrons injected from the left hand n-region into the p-region will tend to diffuse across the p-region to the right hand junction, where they will tend to slide down the potential hill, and thus arrive at the right hand n-region. The three regions are called the emitter, base and collector and it can be seen that the collector current is influenced by the emitter current. It must be kept in mind that not all electrons from the emitter reach the collector and that there is a small base current. A proportion (1-β)

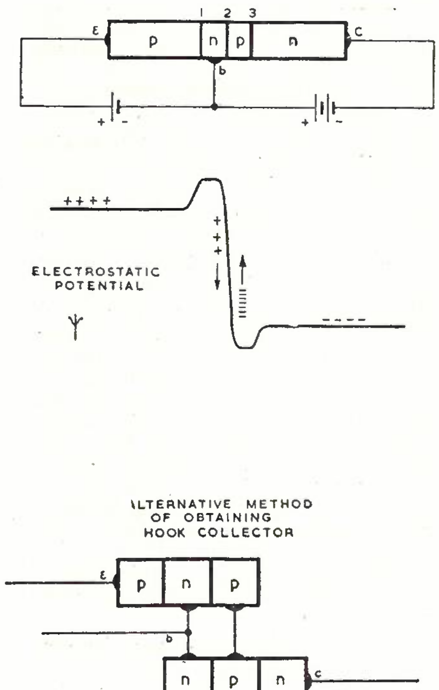


Fig. 6.—The p-n hook collector transistor.

of the injected electrons reaches the base rather than the collector, and hence it is obvious that the current gain from emitter to collector must be less than unity. The current gain from emitter to collector is defined as:

$$\alpha_{ce} = \left(\frac{dI_c}{dI_e} \right) V_c = \text{constant}$$

where I_c = collector current
I_e = emitter current
V_c = collector voltage

α's of the order 0.9 to 0.99 are usual. The transistor can have useful gain, in spite of the fact that α is less than one, due to the fact that its input resistance is low ($\sim$ 100 ohm) whilst its output resistance is high ($\sim$ 1 megohm). This is a direct outcome of its biasing, since the emitter is biased forward, that is in the low resistance direction, whilst the collector is biased in the high resistance direction. It is not necessary to put the input between the emitter and base, with the base grounded. Three types of connections are available, which are shown in Fig. 5. It is of interest to note that, for instance, with the grounded emitter connection α's greater than one can be achieved The current gain would be defined as between base and collector.

$$\alpha_{cb} = -\left(\frac{dI_c}{dI_b} \right) V_c = \text{constant} \quad = \frac{\alpha_{ce}}{1 - \alpha_{ce}}$$

and hence if $\alpha_{ce} = 0.98$, $\alpha_{cb} = 49$

The case for a pnp transistor is, of course, similar, with holes being injected instead of electrons and all bias polarities reversed. Junction transistors are capable of operating with microwatt power consumption, since the collector current will saturate at a voltage of a few times kT/e (.26 eV), drawing a few microamperes. Gains of up to 45 db per stage can be achieved at audio frequencies, but frequency response above a few megacycles, seriously reduces this gain.

Another form of junction transistor is the p-n hook collector. This can take the form of a pnpn or npnp transistor. A p-n-p-n hook collector is shown in Fig. 6 together with the potential distribution under the applied bias. Note that this is similar to an ordinary pnp transistor, modified by an additional n-region at the collector. With the customary bias, junction 1 will be biased forward as usual, junction 2 is biased in reverse and junction 3 will be biased slightly forward. The base width is as usual made small compared to a diffusion length, and the width of the floating p-region is made of a similar length.

The mode of operation is as follows. Holes injected by the emitter will diffuse across the base and under the influence of the electric field at junction 2 will be swept into the "floating" p-region of the collector, which will thus be made slightly more positive with respect to the n collector region, thus biasing junction 3 further in the forward direction. As a result of this, electrons will be injected from the n to the p collector region across junction 3, and since the p-region is small, they will diffuse to junction 2, where they will be swept into the base by the existing electric field. Hence the arrival of holes at the collector leads to electron injection at the base, and if the ratio of total collector current per unit hole current is defined as α', the current multiplication factor α can be defined as $\alpha = \alpha'\beta\delta$, (where δ = portion of total current carried by holes, see Appendix III)

and since values of α' of the order of 100 are encountered, current multiplication factors of 50 are common, with resultant high gain. The collector region potential curve shape gives this type the name of hook collector. It is interesting

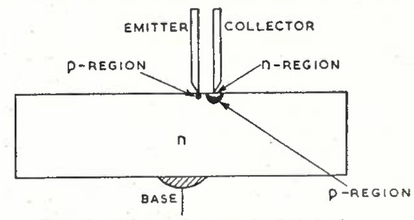


Fig. 7.—The point contact transistor.

to note that a hook collector can also be constructed from a pnp and npn transistor (3).

A junction device of great promise, as it appears to have a better frequency response and greater voltage gain, is the junction tetrode. Here connections are made to both sides of the base, and a potential applied between the two sides. This results in the minority carriers in the base being confined to a small sector of the base, and hence the control of the base over the injected carriers is increased (4).

Point Contact Transistors: The theory underlying the point contact transistor, although the older device, is still in an evolutionary stage, and several theories have been advanced over the past few years without any one mathematical theory being fully satisfactory (5, 6, 7). The explanation given here is of a highly simplified form in order to make it easily understandable.

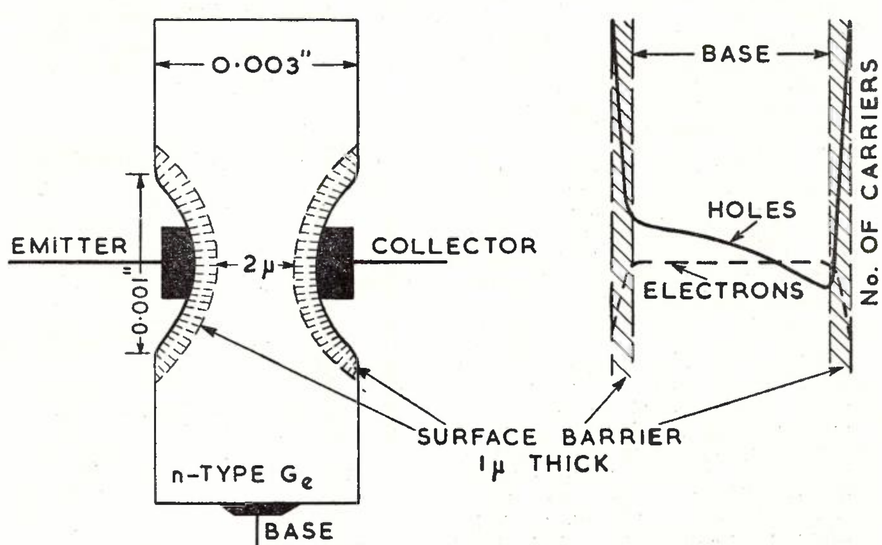


Fig. 8.—The surface barrier resistor.

The point contact transistor is usually made of n-type material, in the form of a thin (20 mils) square or round wafer. To the top of the wafer connections are made by two thin (5 mil. dia.) cat's whiskers with pointed tips, usually made of phosphor bronze, kept on by a pressure of a few grams. The two cat's whiskers which constitute the emitter and collector are about 2 mils apart. An ohmic contact to the underside of the wafer forms the base. With an n-type wafer the emitter is biased forward and the collector in reverse with respect to the base. It is found that the collector current is influenced by the emitter current. The collector action is greatly enhanced by the "forming" process, and in fact no true transistor action can be had without forming. Forming consists of passing a relatively high current pulse from the metal to semiconductors, the pulse duration being of the order of ½ second. It is found that due to the resistance step up, amplification occurs between input and output, but apart from this it turns out that the α of the point contact transistor is greater than unity and usually lies in the range 2 - 2.5. The device is somewhat sensitive to the emitter-collector spacing as can be expected. One explanation for the α greater than unity is based on the fact that a point contact transistor is somewhat reminiscent

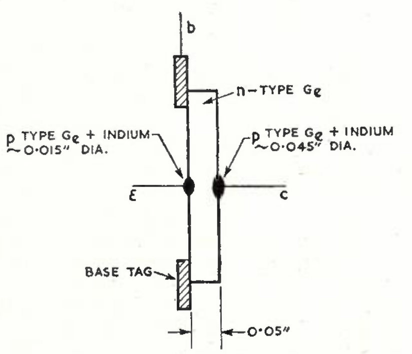


Fig. 9—Fused junction transistor (p-n-p)

of a hook collector. It has been found that current multiplication will only occur after forming and, furthermore, that the cat's whisker collector must contain both copper, which is an acceptor, and also a donor such as phosphorous, during the forming process. It is thus visualised that after forming there is just below the collector contact an n-region surrounded by a p-region, and also a small p-region below the emitter. See Fig. 7. Assuming such a structure, one can explain the point contact transistor action in the terms of the junction hook collector structure. One significant difference between the two devices is that in the junction hook collector the forward impedance is always high, since one or the other of the two collector junctions will always be biased in reverse. However, in the point contact transistor it is found that the forward resistance of the collector is low, and it is visualised that this is due to the fact that with forward bias, the junction between the small n and p-region below the collector breaks down, probably due to the fact that the field density under the collector cat's whisker will be extremely high, as it is sharply pointed. If then this junction breaks down, it will have only low dynamic impedance. For further theories see References 8, 9.

Point contact transistors have a far better frequency response than junction transistors, frequency operation up to about 50 Mcs being common, whilst gains are in the range 20-25 db.

Other Types of Transistor: Photo transistors, both of the point contact and junction type, are being commercially manufactured. In a photo transistor, the emitter is missing and carrier injection proceeds by the admittance of light within one diffusion length of the collector. Providing the light has enough energy, for germanium this means a wavelength of less than 2 μ, transistor action then proceeds according to the usual mechanism. (10, 11). Dark current is usually high. The largest gains are achieved in the npn photo transistor, which acting as a hook collector, corresponds to a photo multiplier.

Several field controlled devices have been investigated. The fieldistor (12) utilizes an electric field to modulate the conductivity of a semi-conductor. Although the gain can be made high, the stability is poor and the frequency response low. In the unipolar transistor (13, 14) the extension of the non-conducting junction barrier with increasing inverse voltage is utilized to control the effective cross-section of the conducting region. This pinch-off effect does not constitute resistivity modulation by

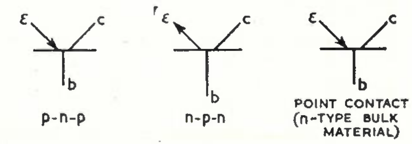


Fig. 10.—Transistor symbols.

injected carriers such as in the junction tetrode, but is due to the transverse electric field. The unipolar transistor has the advantage of a higher frequency response than the junction tetrode, and can have a much higher input impedance although not as high as the fieldistor.

The latest type of transistor is the surface barrier transistor (15). These transistors which are of n-type material only, have broad area contacts plated to each side, and the bulk of the germanium forms the base, with an ohmic contact soldered to one side. The base width between emitter and collector can be made exceedingly small (about 2 x 10^{-4} cm.) by an electrolytic etching technique, and is surrounded on each side by a surface barrier of about half that width. These surface barriers, which are a direct result of the fact that the crystal

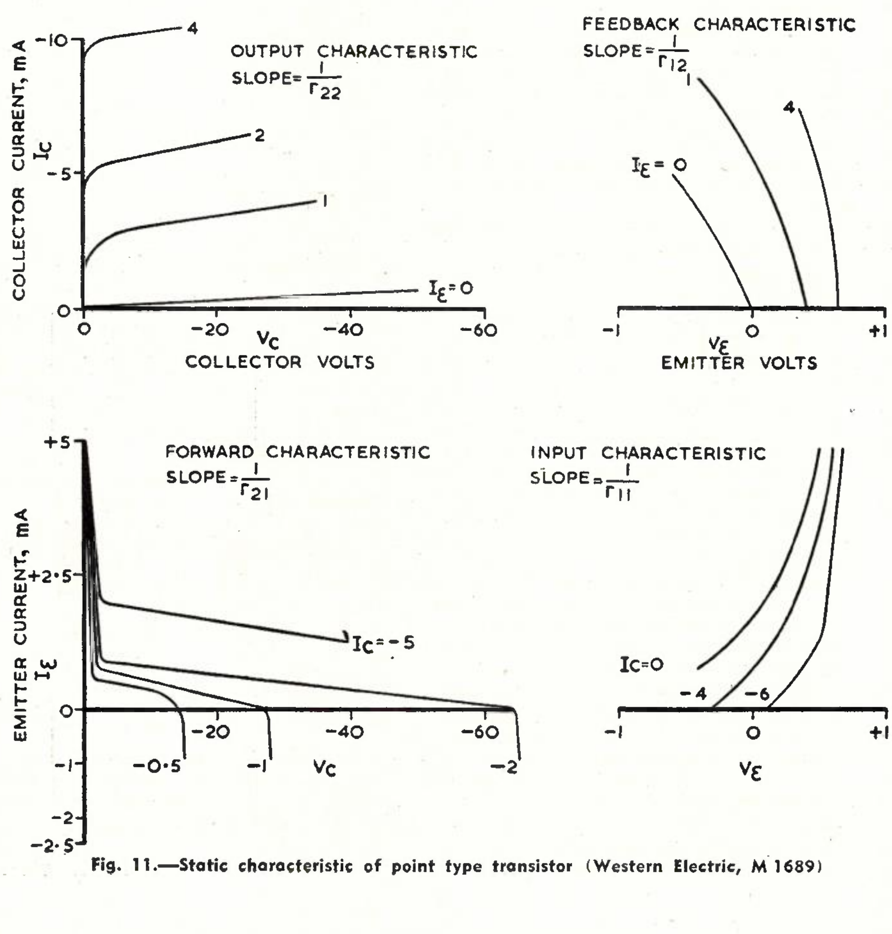


Fig. 11.—Static characteristic of point type transistor (Western Electric, M 1689)

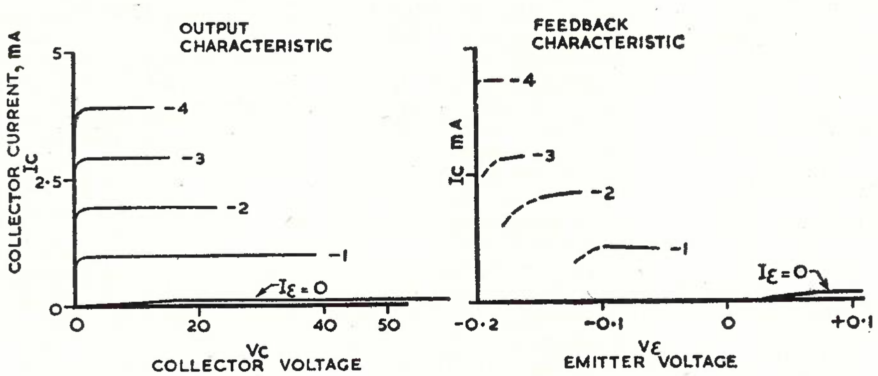


Fig. 12.—Static characteristic of n-p-n junction transistor (Western Electric M 1752).

structure near the surface is disordered, have the property that they contain practically only holes, and hence a space charge is developed, which keeps the electrons inside the material. With the thin base thicknesses possible in this type, it is possible to build up a high concentration gradient from emitter to collector, and hence a large hole current will flow without any appreciable electron current (see Fig. 8) if the collector is biased in reverse and the emitter in the forward direction. The surface barrier transistor is thus able to work at low values of collector voltage and power consumption, whilst having a frequency response comparable to that of the point contact transistor. α is stated to be of the order 0.93 with gains of about 15 db.

Manufacturing Process: As has been pointed out, transistors are required to be made of single crystal, high purity material. The economic and technological problems of high purity raw material, has up till now restricted transistor manufacture to germanium but a process for high purity silicon has recently been announced.

Germanium, after reduction from the oxide, is purified by the zone purification method (16). In this process a narrow bar of germanium inside a graphite "boat" is placed in a quartz tube in an atmosphere of dry hydrogen or nitrogen. Several high frequency coils surround the tube, and the boat containing the germanium is slowly moved along the tube, so that narrow sections (½″) of the germanium are molten at any one time. As the germanium bar moves, the higher melting point impurities are pushed ahead, whilst the lower melting point impurities are left behind. After about 12-15 passes, it is found that nearly all the impurities are at each end of the bar, leaving nearly intrinsic germanium in the centre of the bar. Impurity content can be reduced to about 1 part of 10^9 by this method.

The next step is to obtain single crystals. Here the germanium is melted in a small electric furnace in an atmosphere of hydrogen and a small seed crystal of germanium is dipped into the top of the molten germanium and withdrawn at a rate of about 1″ per hour. The seed crystal continues to grow by taking up germanium from the melt, and single crystals weighing several pounds have been prepared by this method (17).

To obtain either n or p-type material, suitable impurities can be added to the melt during the growing process. If the material is desired to be used for point contact transistors, it will be doped either n or p-type and after a sufficiently large crystal has been grown, the latter will be cut up to the requisite sizes with a diamond saw, etched, and the contacts made. To obtain junction transistors, it would be possible to add alternate donor and acceptor impurities to the melt as the crystal is growing, and hence arrive at a crystal containing alternate layers of p and n-type conductivity.

A more suitable method, however, is the fused impurity method. Here a wafer of say, n-type material is cut from a crystal, and small pellets of an acceptor impurity such as indium, are fused to the two sides of the wafer at a temperature below the melting point of germanium (936° C), but above the melting point of indium (500° C). This gives a pnp transistor. (See Fig. 9). Suitable etching treatment and the soldering of ohmic contacts is then carried out.

Another commercial process consists of altering the speed of the crystal growing rate, as it is found that at high growing rates, germanium has a high solubility for donors and a low solubility for acceptors, giving n-type material, and that at slow growing rates the respective solubilities are reversed. Hence the intrinsic germanium in its molten form has suitable acceptor and donor impurities added, and by means of a seed crystal the growing process is initiated and the rate of growing altered as desired. It must be pointed out that in any junction transistor it is usual to have the emitter and collector region carrier density of different values.

All types of transistors require that they be shielded from light and moisture, and hence it is usual to mount them in a capsule, often hermetically sealed, and/or to set them in some opaque thermosetting plastic such as Araldite.

Transistor Circuit Aspects: The usual symbols for the various types are shown in Fig. 10. Note that only the emitter is shown with an arrow head, the direction of the arrow indicating the electron flow.

A transistor is a four terminal device, hence there will be two independent variables, and the other two parameters will be defined in terms of the former. Two types of conventions have been current in the literature, depending on which parameter is made the independent variable, and the characteristic curves shown in Figs. 11 and 12 are drawn with collector voltage and emitter current (or emitter voltage) as independent variables.

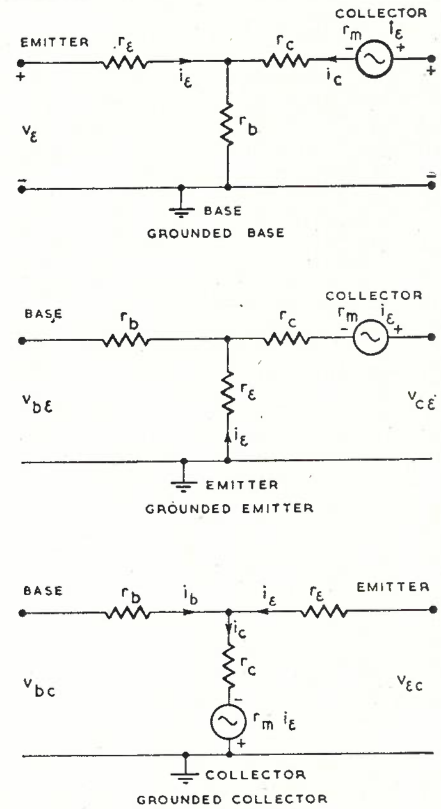


Fig. 13.—Small signal equivalent 'T' circuits at low frequency.

The set of four characteristic curves as shown in Figs. 11 and 12 are related to four measurable parameters of the transistor:—

(a) Open circuit input impedance

$$Z_{11} = \frac{V_e}{I_e} \quad (I_c = O)$$

(c) Open circuit feedback impedance

$$Z_{22} = \frac{V_c}{I_c} \quad (I_e = O)$$

(c) Open circuit feedback impedance

$$Z_{12} = \frac{V_e}{I_c} \quad (I_e = O)$$

(d) Open circuit forward transfer impedance

$$Z_{21} = \frac{V_c}{I_e} \quad (I_c = O)$$

The equivalent circuit of a transistor is usually derived by the "black box" analogy, familiar in electrical theory. Remembering that a transistor is a four-pole active network, the equivalent T-circuits of Fig. 13 are derived. An equivalent π network can also be developed. As shown here, the circuits are for small signal, low frequency application and hence capacitances are neglected, and all impedances treated as simple resistances. The equivalent generator $r_m i_e$ is included to satisfy the active network stipulation, and i_e is

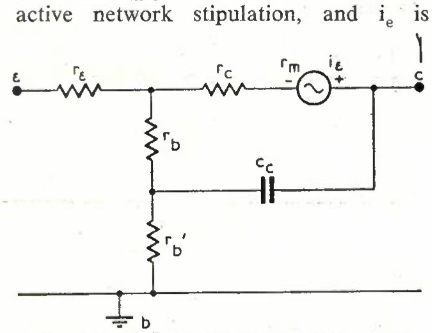


Fig. 14.—High frequency, equivalent 'T' grounded base, circuit.

defined as the current through r_e flowing towards the junction point J. r_m is called the mutual resistance for the network. The following equalities can now be derived, for instance for the grounded base connection:—

$r_{11} = r_e + r_b$

$r_{12} = r_b \qquad \alpha = \dfrac{r_b + r_m}{r_b + r_c} = \dfrac{r_{21}}{r_{22}}$

$r_{21} = r_m + r_b$

$r_{22} = r_c + r_b$

From the complete equivalent circuit of a grounded base transistor, incorporating the source voltage V_g of internal resistance R_g and the load resistance R_L it is possible to calculate the input and output resistance:

Assuming $r_m \gg r_b$

$r_c \gg r_b$

Input resistance $r_i =$

$$r_e + r_b \left(\frac{r_c (1-\alpha) + R_L}{r_b + r_c + R_L} \right)$$

Output resistance $r_o =$

$$r_c \cdot \frac{r_e + r_b (1-\alpha) + R_g}{r_e + r_b + R_g}$$

Available voltage gain

$$= \frac{\text{Voltage delivered to load}}{\text{EMF from generator}}$$

$$= \frac{R_L (r_b + r_m)}{(R_g + r_b + r_e)(R_L + r_b + r_c) - r_b(r_b + r_m)}$$

Maximum voltage gain $G_{max} =$

$$\frac{r_c + r_b}{r_e + r_b} \cdot \alpha$$

Available power gain P =

$$\frac{4R_L \, R_g (r_b + r_m)^2}{\left((R_g + r_b + r_e)(R_L + r_b + r_c) - (r_b + r_m) r_b\right)^2}$$

From the above it can be seen that both input and output resistance can be negative for a point contact transistor where α is greater than unity, whilst a junction transistor, whose α is always less than one has, in all cases, positive input and output resistances. This shows that point contact transistors are short circuit unstable ($R_L = 0$), whereas the junction transistor is unconditionally short circuit stable. It can be seen that a large base resistance r_b will be detrimental to stability, as will be a low emitter resistance. If as usual, it is assumed that r_b is small compared with r_c or r_m, the stability criterion can be expressed approximately as:

$$\frac{r_e}{r_b} > \alpha - 1$$

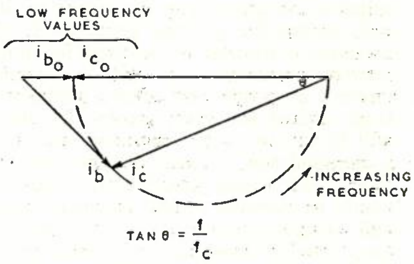


Fig. 15.—High frequency current vector diagram.

Typical values for important parameters are given in the following table:

	Point Contact	Grounded Base Connection Junction
r_e	120 ohms	25 ohms
r_b	75 ohms	100 ohms
r_c	15000 ohms	1 megohm
r_m	38000 ohms	.95 megohm
R_g	500 ohms	25 ohms
R_L	30000 ohms	50000 ohms
α	2.5	.95
R_I	145 ohms	35 ohms
R_o	17000 ohms	370000 ohms
G	32 db	28.5 db
P	19.5 db	32 db

When high frequency applications are required, the equivalent circuit must be modified to take into account the collector barrier capacitance. Fig. 14 shows one form of equivalent circuit at high frequency. The capacitance C_c is usually of the order of 5 - 40 $\mu\mu$F. This capacitance can be expressed as

$$C_c = \frac{e}{kT} \cdot \frac{W^2 I_e}{2D}$$

where W = width of base region
D = diffusion constant

The cut off frequency of a transistor is defined as the frequency at which the gain has dropped 3 db from its value at low frequencies. A general form of equation for cut off frequency is

$$f_c = \frac{D}{\pi W^2} \text{ c/s}$$

Thus it becomes obvious that the base region width in a junction transistor or the cat's whisker spacing in a point contact type must be small for high frequency cut-off. Other parameters which alter with frequency are α and the base current. In the case of increasing base current this results in additional negative feedback through the base resistance, and hence reduced gain. See Fig 15. In general the cut-off frequency of a point contact transistor is far superior to that of the junction transistor, representative values being in the range 10-50 Mc/s and 500 kc/s- 2Mc/s respectively. The type of circuit used, that is grounded base, emitter, etc., leads also to variations.

In using transistors, due care must be taken that they will not be exposed to excessive ambient temperatures, a limit of about 70°C. being usual for germanium. This is so because the saturation current I_{co}, that is the collector current at zero emitter current is temperature sensitive, as can be seen by referring back to the general rectification formula of Appendix III. The collector impedance is also found to decrease with temperature increase (18). It is to be noted that silicon transistors can be used up to temperatures of the order of 200° C, and as a consequence, much higher power dissipation can be allowed with this type of material.

Transistors are inherently more noisy than vacuum tubes, and it is found that transistor noise is frequency dependent, decreasing approximately 11 db per octave. Noise figures are usually quoted at 1000 c/s. and representative figures for junction and point contact units might be 10 - 20 db and 35 - 45 db respective (19). Low noise operation is assisted by operating with low collector voltage and optimum input matching. At radio frequencies, noise figures of about 3 db are encountered for junction types. Reliability and life studies are as yet not conclusive, due to the fact that long range extrapolation must be

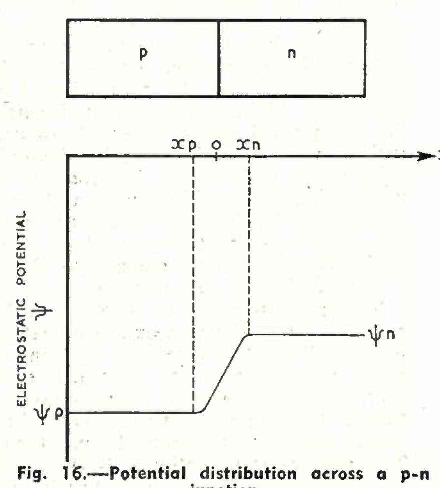


Fig. 16.—Potential distribution across a p-n junction.

used, but it appears that the life of the transistor will be at least as long as that of the average vacuum tube, and probably much longer. (21).

Conclusion. This paper has attempted to outline the field of transistor physics, and it has, of course, been necessary to omit much that is vital for the proper design and operation of transistors. A voluminous bibliography has come into existence and several books have been published which treat the subject extensively (see References) to which reference can be made.

Transistors have opened up a tremendous field of application in both communication and instrumentation engineering, making possible considerable savings in space and power consumption. Whilst it is futile to hide the presently existing limitations of transistors such as costs, high noise, low current handling ability and poor reproducibility, these factors can, in the main, be regarded as being due to the early state of development. Significant improvements have been made in all cases, and the transistor of today represents such a step forward from the early transistors of 1948 that it is not too optimistic to hope that most of the above difficulties and limitations will be overcome in the next five years. In this connection it must be mentioned that great interest now centres in the development of transistors made from silicon, and looking into the future, from intermetallic compounds such as aluminium antimonide. These materials have some great advantages in semiconductor characteristics, and furthermore, the raw materials are more common and hence much cheaper than germanium. Fortunately the component miniaturisation field is keeping step with transistor development, so that miniature resistors, capacitors, transformers, etc., as well as tiny mercury batteries are now available.

One thing is certain; any worker in the field of radio, electronics or telecommunications should familiarise himself with this new device as it promises to be an active circuit component in all these fields within a very few years.

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Appendix I

Diffusion Length—One Dimensional Case

Assume that due to an injected burst of radiation, electron-hole pairs are created at a point $x = O$. If we assume n-type material, and hence consider the excess hole concentration, $p - p_n$, where p is the actual hole density and p_n the number of free holes immediately after the incidence of the radiation, some of the excess holes will diffuse in the x-direction and their density will have fallen by $1/e$ within one diffusion length L_p. In order to derive L_p we use the continuity equation (in the one dimensional case).

$$\frac{dp}{dt} = (\text{Generation-Recombination}) - \frac{1}{e}\frac{dI_p}{dx}$$

here generation $= O$

$$\text{recombination} = \frac{p - p_n}{T_p} \text{ where } T_p =$$

lifetime for holes in n–type material

$$\text{hence } \frac{dp}{dt} = -\frac{p - p_n}{T_p} - \frac{1}{e} \cdot \frac{dI_p}{dx} = O \text{ for}$$

steady state

$$\text{Now the current density } I_p = -eD_p \cdot \frac{dp}{dx}$$

where D_p is the diffusion constant for holes given by:

$$D_p = \frac{kT}{e} u_p \text{ (Einstein's equation)}$$

($= 47$ cm²/sec. for Ge at room temp.)

$$\therefore \frac{p - p_n}{T_p} = D_p \frac{d^2p}{dx^2}$$

and solving for excess hole concentration,

$$p - p_n = (p - p_n)_{x=O} \exp\left(\frac{-x}{(D_p T_p)^{1/2}}\right)$$

where the diffusion length is defined as

$$L_p = (D_p T_p)^{1/2}$$

Example: Assume n-type material with

$T_p = 50$ microseconds

$D_p = 47$ cm²/sec.

then $L_p = 0.5$ mm.

Appendix II

Theory of p-n Junction

(See Fig. 16)

Electron current density I_n

$$= nev_n = + eu_n n \frac{d\psi}{dt} - e D_n \frac{dn}{dx}$$

Hole current density I_p

$$= pev_p = -eu_p p \frac{d\psi}{dt} - eD_p \frac{dp}{dx}$$

The first term is current due to electrostatic field, whilst the second term is due to diffusion, and ψ is the electrostatic potential in equilibrium (contact P.D. between p and n region).

since $u = \frac{e}{kT} D$ (Einstein relation)

$$I_n = eu_n (n \frac{d\psi}{dx} - \frac{kt}{e}\frac{dn}{dx})$$

$$I_p = -eu_p (p \frac{d\psi}{dx} + \frac{kT}{e}\frac{dp}{dx})$$

In equilibrium, we must have

$$I_n = I_p = O$$

hence $n \frac{d\psi}{dx} = \frac{kT}{e}\frac{dn}{dx}$ and $p \frac{d\psi}{dx} = -\frac{kT}{e}\frac{dp}{dx}$

solving the above equations,

$n = C \exp.(\frac{e\psi}{kT})$ $\quad p = D \exp.(\frac{-e\psi}{kT})$,

where C and D are constants of integration.

But since $np = n_i^2$, $CD = n_i^2$

If we assume $C = n_i \exp(\frac{-e\phi}{kT})$

$$D = n_i \exp(\frac{e\phi}{kT})$$

ϕ = Fermi level

we have $n = n_i \exp(\frac{e(\psi - \phi)}{kT})$

$$p = n_i \exp(\frac{e(\phi - \psi)}{kT}) \qquad \ldots\ldots(1)$$

now far from the junction

$p = N_a$ (acceptor density)

$n = N_d$ (donor density)

ψ_p = electrostatic potential in p–region

ψ_n = electrostatic potential in n–region

∴ Contact potential

$$= 1n \frac{N_a N_d}{n_i^2} = \frac{e(\psi_n - \psi_p)}{kT}$$

At room temperature, substituting for k, T and e,

$$\psi_n - \psi p = 0.026 \ 1_n. \frac{N_d N_a}{n_i^2}$$

volts.

Example:

If $N_a = 10^{18}$, $N_d = 10^{14}$, $\psi_n - \psi_p$ = 0.2 volt.

The distribution of ψ near the junction can be obtained from Poisson's equation.

$$\frac{d^2\psi}{dx^2} = -\frac{4\pi\varphi}{K}$$

φ = space charge density

K = dielectric constant

If all donors and acceptors are ionised,

$$\varphi = (p - n + N_d - N_a)\, e$$

hence, $\frac{d^2\psi}{dx^2} = -\frac{4\pi e}{K}(p - n - N_a + Nd)$

Neglecting the contribution from p and n near junction, as these depend exponentially on ψ, from equation 1,

$$\frac{d^2\psi}{dx^2} = \frac{4\pi eN_a}{K} \quad \text{(x less than O)}$$

$$\frac{d^2\psi}{dx^2} = -\frac{4\pi eN_d}{K} \quad \text{(x greater than O)}$$

hence,

$$\psi = \frac{2\pi eN_a}{K}(x - x_p)^2 + \text{constant}$$

(x less than O)

$$= \frac{2\pi eN_d}{K}(x - x_n)^2 + \text{constant}$$

(x greater than O)
(See Fig. 16)

The negative space charge for x less than O, due to ionised acceptors unaccompanied by an equal density holes, or the positive space charge for x greater than O, due to ionised donors not accompanied by an equal density of electrons, is given by above equation.

Since $\frac{d\psi}{dx} = O$ at the junction, $\frac{x_p}{x_n} = -\frac{N_d}{N_a}$, and if N_a is very much greater than N_d, such as in a fused impurity type, $|x_p| << x_n$, that is the depletion region extends further into the n–region than into the p–region.

Appendix III

Rectification Formula

Assume that a pn junction has a potential difference V applied, and consider the hole current only, assuming that thermal generation of holes is constant

we have $I_p = \frac{eD_p}{L_p}(p - p_n)_{x=x_n}$

where p_n = equilibrium density of holes in n–region

since $p = p_n \exp(\frac{eV}{kT})$

hence $I_p = \frac{eD_p}{L_p} p_n (\exp \frac{eV}{kT} - 1)$ ....(1)

for large negative P.D. (i.e. n–region positive) there will be only the thermal hole current I_{ps}.

$$-I_{ps} = -\frac{eD_p}{L_p} p_n = \frac{kT}{e}\frac{b}{(b+1)^2}\frac{\delta_i^2}{\delta n L_p}$$

where $b = \frac{v_n}{u_p}$ approx.

= 2.1 for germanium

δ_n = conductivity of n–type material

δ_i = conductivity of intrinsic material

(1) becomes

$$I_p = I_{ps} (\exp. \frac{eV}{kT} - 1)$$

Similarly the electron current is given by

$$I_n = I_{ns} (\exp \frac{eV}{kT} - 1)$$

and hence total current density for junction is given by

$$I = (I_{ps} + I_{ns}) (\exp \frac{eV}{kT} - 1)$$

A concept of importance in transistor operation is the hole or electron injection efficiency

hole injection efficiency δ_p

$$= \frac{I_p}{I} = (1 + \frac{I_{ns}}{I_{ps}})^{-1} = 1 - \frac{\delta_n L_p}{\delta_p L_s},$$

assuming $I_p >> I_n$.

ENGINE-GENERATOR CHARGING SETS FOR RURAL AUTOMATIC EXCHANGES

N. D. STRACHAN, B.E., A.M.I.E.E., A.M.I.E., Aust. and C. M. PIPER.

Summary

Charging the batteries of a rural automatic exchange (R.A.X.) where commercial power is not available presents many difficulties. This article describes a reliable means of charging by the use of an engine driven generator situated at the R.A.X., and remotely controlled from the parent exchange which is not necessarily a Technician's head station.

Introduction

At R.A.X.s which are so far from their parent exchange that the resistance of the trunk lines exceeds 100 ohms, charge-over-trunk methods cease to be practicable. This resistance represents a route distance of about 11 miles if metallic charging is used. The distance can be increased if earth circuit charging is used, but as this method introduces corrosion problems where the earth resistance is high, it is not favoured. For larger "C" type installations the output of the charge-over-trunk is not sufficient to maintain the batteries at the correct voltage even if it is possible to use this method, and so other means must be selected.

Furthermore, many "B" type R.A.X.s are installed with only one trunk line, which, being used for a considerable part of the day for calls, reduces the time of charging over the trunk. Periodically replacing the R.A.X. batteries by a charged set is impracticable where roads are impassable during wet weather.

To overcome the difficulties of charging the batteries of R.A.Xs in distant localities, petrol engine generators are installed with remote control features to enable them to be started and stopped from the parent exchange.

Equipment

The prime mover is a 2-3 H.P. 4-stroke water cooled internal combustion engine. The petrol tank capacity is large enough to permit 24 hours continuous running. The engine and generator are mounted on a steel channel base and coupled together with a vee belt. The 50/70 volt generator has an output of 500/1000 watts and is fitted with a series starting winding. The whole assembly, including the water tank, is fixed to a concrete base and housed in a small prefabricated hut, situated a short distance from the R.A.X. to reduce fire risk.

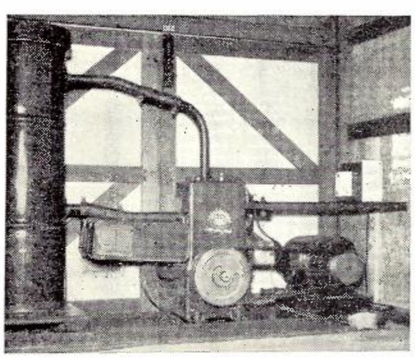


Fig. 1.—Engine-generator set.

The unit is similar to commercial home lighting plants, except that the generator has been wound for charging 48 volt batteries. Figs. 1 and 2 show the general arrangement of the unit. The control panel with the associated equipment shown in Fig. 3 is mounted on the miscellaneous apparatus rack inside the R.A.X. building, occupying the space normally allocated to the power rectifier.

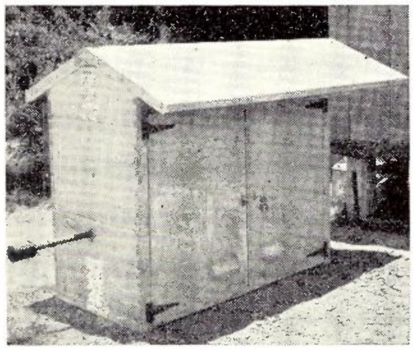


Fig. 2.—Engine-generator hut.

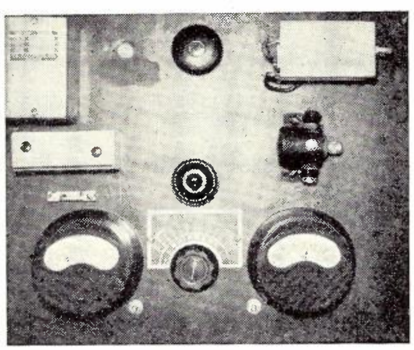


Fig. 3.—Engine-generator control panel on M.A.R.

The charging rate is varied by adjustment of the field rheostat to a value determined by the required periodicity of charging based on the rate of discharge of the batteries.

Figure 4 shows the layout of the control panel. Connections between the engine-generator and the control panel equipment are made using P.V.C. insulated cable carried in underground galvanised pipe.

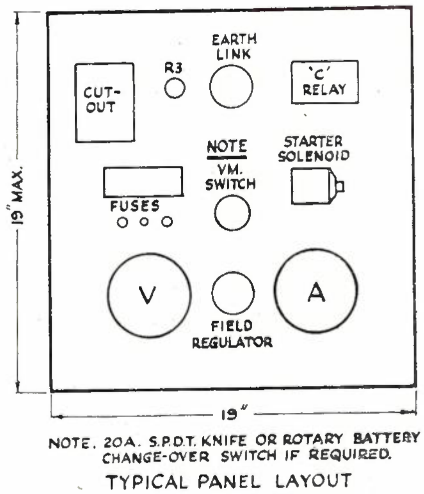


Fig. 4.—Layout of control panel.

Facilities

The facilities provided for use with "B" and "C" type R.A.X.s are—

(a) Starting of engine over a selected trunk line from the parent exchange.
(b) Stopping the engine over the same trunk line from the parent exchange.
(c) Prevention of interference with the control circuit by subscribers.
(d) Cessation of cranking of engine if it does not commence to run within a reasonable time.
(e) Identification by appropriate tones of the condition of the charging circuit.
(f) An automatic alarm in the event of charge failure, which, in the "C" type installation, is extended to the parent exchange.

Operation

General.—The circuits for "B" and "C" type R.A.X.s are shown in Figs. 5 and 6 respectively. The control equipment may be associated with any trunk line to an R.A.X. but, since alarms are usually extended over the first trunk from a "C" type exchange, another trunk line is used, if possible, in this instance. The start key is wired in the negative line and the stop key is wired in the positive line, and the operation of either key connects positive battery to relays in the control circuit. When it is desired to charge the R.A.X. batteries, a special number, allotted in the final selector multiple, is dialled over the trunk line to busy the trunk line against intrusion as well as preparing the control circuit for the start or stop signal.

"B" Type R.A.X. When the final selector tests in after the number has been dialled, relay P operates. Contacts P3 and P6 disconnect the trunk line circuit from the line, but maintain the loop through the 1,000 ohm resistor R1. Contact P1 operates relay PP, and contacts P2 and P4 prepare the circuits for the "start" and "stop" relays, ST and SP.

Contact PP1 operates relays SC and Z, and allows electrolytic condensers C3 and C4 to charge.

Contacts PP2 and PP3 extend a start condition to the ring and tone circuits.

Contact PP4 completes a circuit for the transmission of tones indicating the state of the circuit.

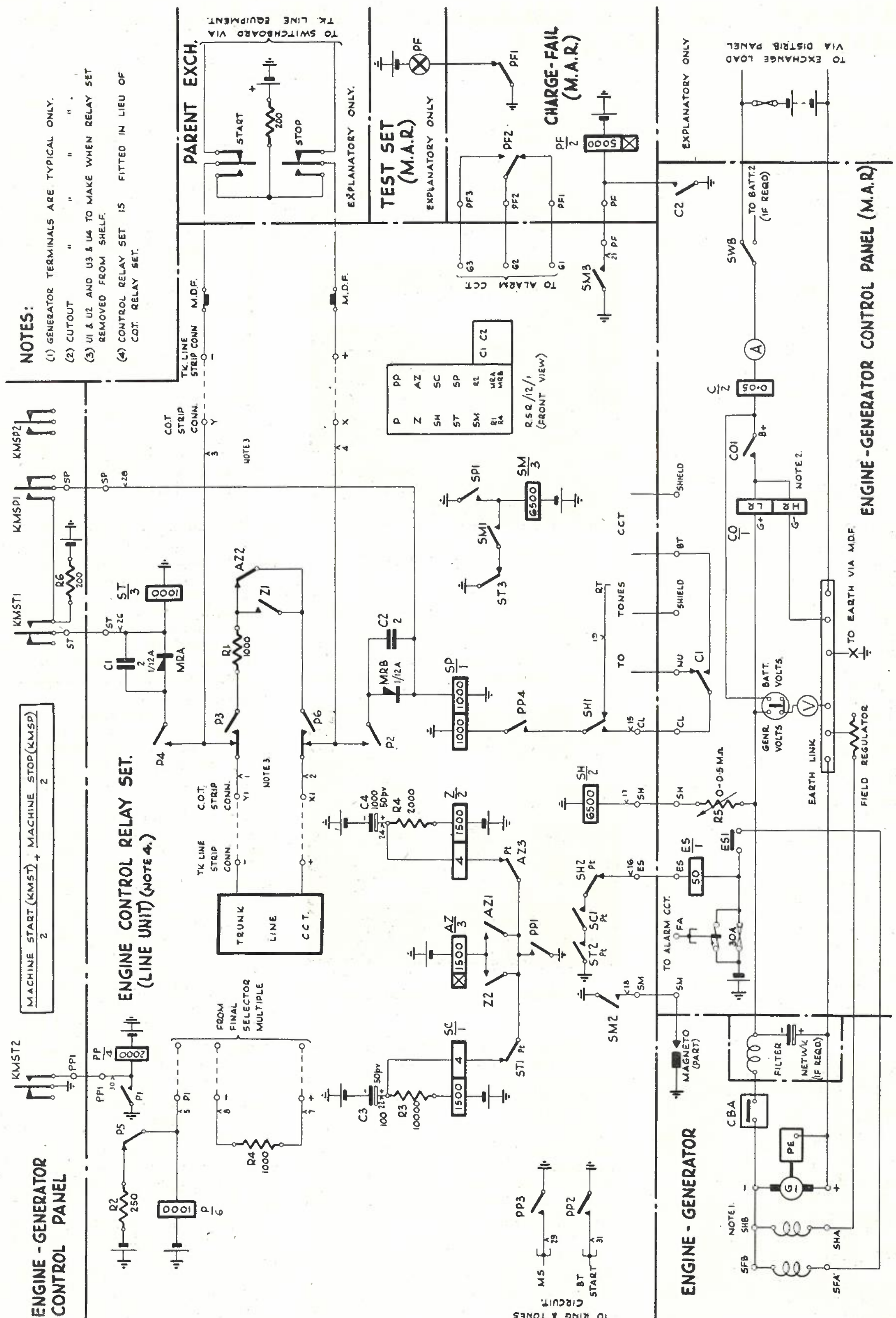


Fig. 5.—Circuit for "B" type R.A.X.

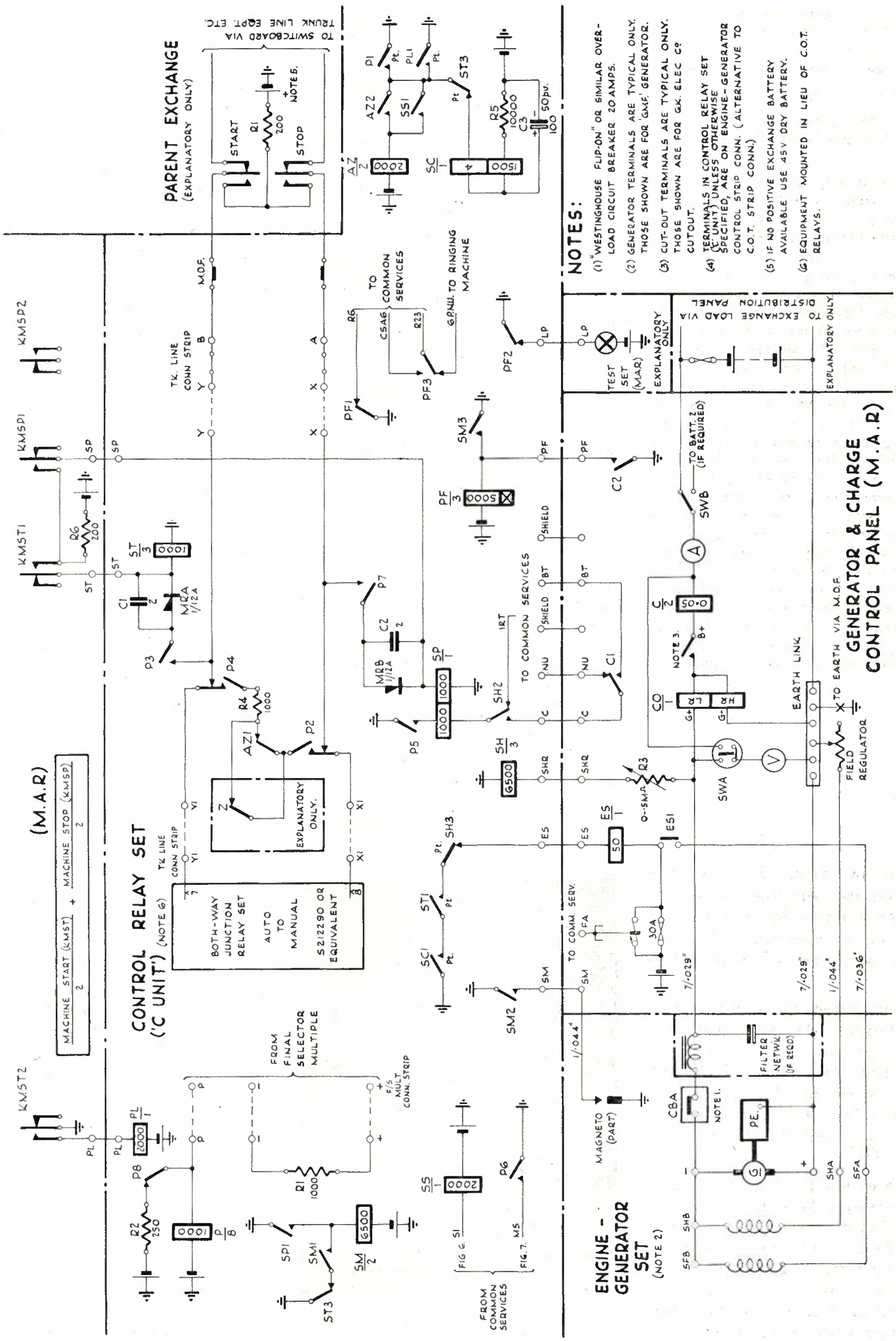


Fig. 6.—Circuit for "C" type R.A.X.

Receipt of ringing tone at the parent exchange indicates that the engine is not running. If it is heard after the start key has been operated it indicates—

(a) that the engine is not running, or

(b) that the engine is running but there is no output from the generator.

Relay SC prepares the circuit for the start solenoid ES, which is a commercial car starter solenoid wound for 50 volt working. Contact Z1 maintains the loop on the trunk line circuit and operates relay AZ. Relay AZ operating opens the circuit of relay Z at contact AZ3, and also leaves the loop on trunk line circuit dependent on contact AZ2. The trunk line circuit is therefore held for the combined release periods of relays AZ and Z which equals about 30 seconds. This time is sufficient to start the machine. Momentary operation of the start key at the parent exchange connects positive battery to the negative line to operate the start relay ST. Contact ST3 releases relay SM and contact SM2 removes the short circuit from the magneto contacts. Contact ST2 completes the circuit for the engine start solenoid which connects the exchange battery to the series field causing the generator to run as a motor. After one or two revolutions the engine fires. In the event of the engine not starting, relay SC releases after a delay of three to four seconds and contact SC1 opens the circuit of the solenoid ES, thus disconnecting the exchange battery from the generator.

After the generator output has reached a predetermined voltage, relay SH operates. Contact SH2 opens the solenoid circuit and SH1 connects NU tone to line indicating that the engine is running and that the generator voltage has reached the required potential. The cut-out CO operates and completes the charging circuit through relay C. This relay operates and connects busy tone to the line via contact C1 to indicate charging is taking place and also maintains relay PF operated in the charge fail circuit via contact C2. If failure of charge occurs, PF releases and operates the alarm circuit.

To stop the machine the special number is dialled and the stop key is depressed momentarily to operate relay SP. Contact SP1 operates relay SM which short circuits the magneto at SM2. Contact SM3 holds relay PF operated and at SM1 completes a locking circuit for itself. The release of the circuit is dependent again on the release lags of relays AZ and Z.

To enable the machine to be started at the R.A.X. without interfering with the trunk line, keys are mounted on the miscellaneous apparatus rack. The relay equipment is assembled in a relay set mounting and occupies the charge-over-trunk relay set position in the unit.

"C" Type R.A.X. The circuit is essentially the same as for the "B" type R.A.X. except that the release of the trunk line circuit is controlled by the S and Z pulses from the "C" unit and the relays are strip mounted in place of the charge-over-trunk relays normally provided.

Other Types of R.A.X. A circuit for use in conjunction with the S.T.C. 50 line "B" type R.A.X. has been developed. As well as embodying the remote control features described above, the engine-generator units at these installations are automatically controlled by the ampere-hour meters which are part of the S.T.C. Rural Automatic exchange equipment.

Conclusion

The provision of the remote control facilities obviates the necessity for a Technician to visit the R.A.X. to charge the batteries, a visit which could occupy a whole day if the R.A.X. is not easily accessible.

The procedure usually followed is to charge the batteries when on a regular visit to the R.A.X. to carry out routine maintenance or read the meters, and before leaving to ensure that the fuel and water tanks are full. The batteries may be then charged again as required for a total period of about 24 hours without revisiting the R.A.X.

MR. L. C. BOTT

On July 14, 1954, Mr. L. C. Bott retired from the Department, at the age of 65. At that time Mr. Bott held the position of Superintending Engineer, Perth, to which he was appointed in 1940.

Mr. Bott joined the Department as Junior Assistant Engineer, Perth, in 1908. He passed through the positions of Draftsman, Assistant Engineer, State Section Engineer and Divisional Engineer and in 1927 was appointed to the position of Assistant Superintending Engineer, Perth.

In 1936 he was promoted to the position of Assistant Superintending Engineer, Melbourne, and then transferred back to Adelaide to take up the duties of Superintending Engineer. In 1940 he returned to W.A. to the position of Superintending Engineer, Perth, where he remained until his retirement.

MR. L. C. BOTT

Throughout his Departmental career Mr. Bott has shown great interest in the training of Cadet Engineers and Technicians and for many years had an active part in this training by lecturing to junior technicians on Departmental subjects. His guidance and assistance to those in doubt and his mature judgment on all matters was always forthcoming.

Mr. Bott has always shown a keen interest in sporting undertakings and has led an active sportsman's life. He played State Cricket for many years and represented the State in a number of interstate matches, captaining the W.A. Eleven against visiting English teams in 1922-23 and 1923-24. He is a keen gardener and no doubt in his retirement will be able to pursue this hobby with greater pleasure.

A DIRECT READING TRAFFIC RECORDER

L. M. WRIGHT, A.M.I.E.Aust.

Introduction

The provision of any service to the community must be based on the demand, either existing or potential for that service. Any provision in excess of the requirement means waste, and could lead to serious loss. In providing telephone service for the community, the telephone engineer has to strike a balance between the possibility that all subscribers could wish to make a call simultaneously, and the cost factor which makes it prohibitive to provide for this remote possibility. Each administration has its own policy regarding the grade of service which it considers reasonable, and it is usual to allow a poorer grade of service for an abnormally busy period such as Christmas or Easter, fire, flood or earthquake, rather than provide additional equipment which could not be used effectively throughout most of the year.

The provision of switching equipment is based not only on the expected number of subscribers in the area to be served, but also on what may be termed the telephone usage characteristics of the subscribers concerned. In effect one wishes to know the answers to the following questions:—

How many calls does the subscriber make?
When does he make them?
Whom does he call?
How long do they talk together?
How many calls does he receive?
When does he receive them?
Who calls him?
How long do these calls take?

To ask the subscribers these questions directly would result in some interesting, and perhaps, some pointed comments, but would probably give little accurate information, and a large amount of work would be necessary to assemble the information into useful form. Only a summary of the impersonal parts of the answers to the above questions is required, however, and will usually be expressed as traffic quantities on a trunking plan. With accurate information, the engineer may plan switch provision at each switching stage with confidence, knowing that sufficient switching equipment will be available to give the required grade of service. Without such accurate information he must either use a liberal hand, or else guess and hope for the best, and neither of these alternatives is satisfactory from an engineering point of view.

Having said then that there is a need for an accurate knowledge of the telephone traffic to be expected in various sections of the exchange, it should also be realised that the cost of obtaining it should not outweigh the advantage of having it available. An early recording method used consisted of a visual count of the number of switches in use in various groups of circuits, and required the use of many observers, and often disrupted normal routines, etc. For these reasons, measurements were not often taken because of the cost and inconvenience involved.

Various switch counting arrangements have since been developed giving results at least as good as, and normally much better than, the visual counts, with much less expenditure of labour. The standard traffic recorder which has been installed in many Australian exchanges is a good example of this type of recorder. While reasonably satisfactory results may be obtained with this recorder, it has been found somewhat cumbersome to use in practice and a simplified recorder has been developed and installed at Unley and Semaphore Exchanges in the Adelaide network in South Australia. The objective has been to retain the desirable characteristics of the standard recorder, but to have a cheaper installation, and a simplified recording and calculating procedure. The recorder developed does in fact have the following advantages compared with the standard recorder:—

(a) It is a cheaper installation.
(b) Recording and calculating work is simplified.
(c) Reading of traffic throughout the whole exchange may be taken concurrently.
(d) Traffic at any point in the exchange may be read directly at any time.

In addition, grading analysis is possible, and the accuracy of readings obtained is of the same order as can be obtained with the standard recorder.

General Description

The general principle of the resistor type of traffic recorder is well known since it is in use in several States, and this recorder is merely an extension of that described by W. M. Squair in Telecommunication Journal, Volume 6 No. 5 (October 1947), and the systems installed at Unley and Norwood exchanges in South Australia in 1944 to 1946. The basic arrangement is shown in Fig. 1,

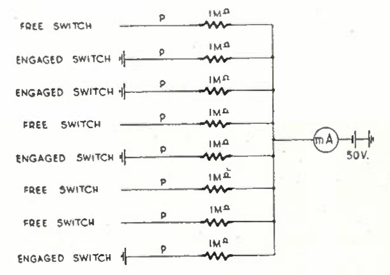


Fig. 1.—Basic arrangement of resistor type traffic recorder.

each switch engaged earthing the P lead, and adding 0.05 mA to the current through the meter under the condition shown.

In this installation the resistors are mounted directly on the shelf jacks of the switches or repeaters between U9 and a spare U jack (occasionally it is necessary to provide a separate terminal for one end of the resistor if no spare U jack is available). Fig. 2 shows the resistors mounted in this manner. The normal traffic recorder wire is transferred from U9 to the other end of the resistor. Arrangement into the measuring groups is accomplished by strapping on the traffic recorder block (the actual method will be discussed under Analysis Arrangements) and leads extended to the control rack via a tie cable. The recording meter is connected to the various groups by means of a uniselector which is used to select the particular group required, as shown in Fig. 3.

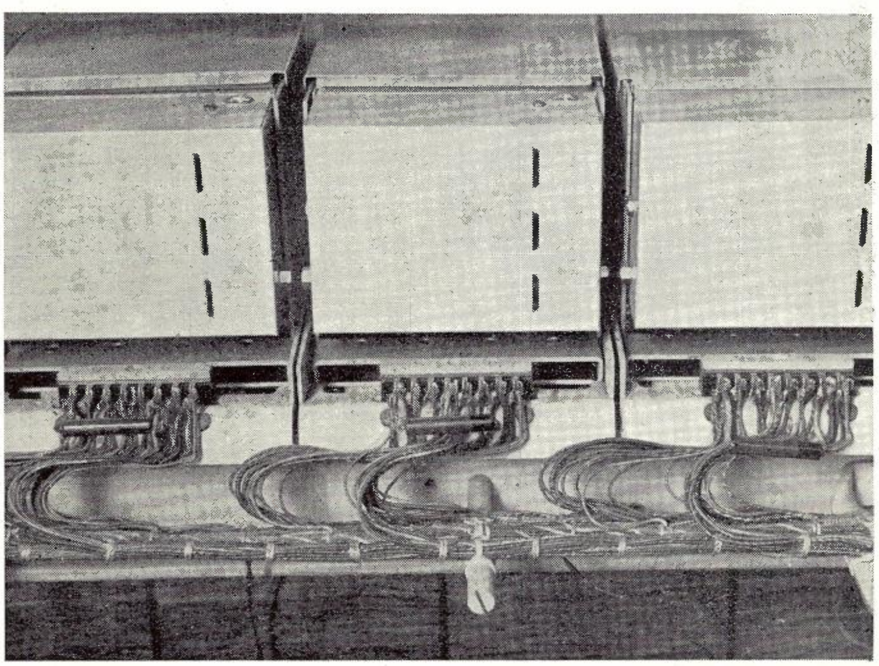


Fig. 2.—Traffic recorder resistors mounted on U-jacks of group selectors.

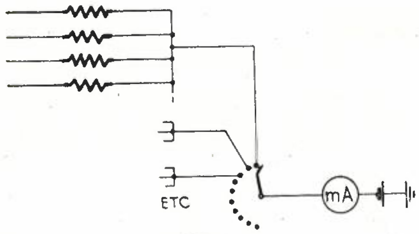


Fig. 3.

ing floor space. Fig. 4 shows the control rack at Semaphore exchange.

Meter and Scale Used

As a design objective it was desired to have a scale which would be open for small T.U. readings, with the scale closing progressively for higher readings. The use of more than one scale is not ideal as it is necessary to range switch, with the consequent possibility of false readings by use of the wrong scale.

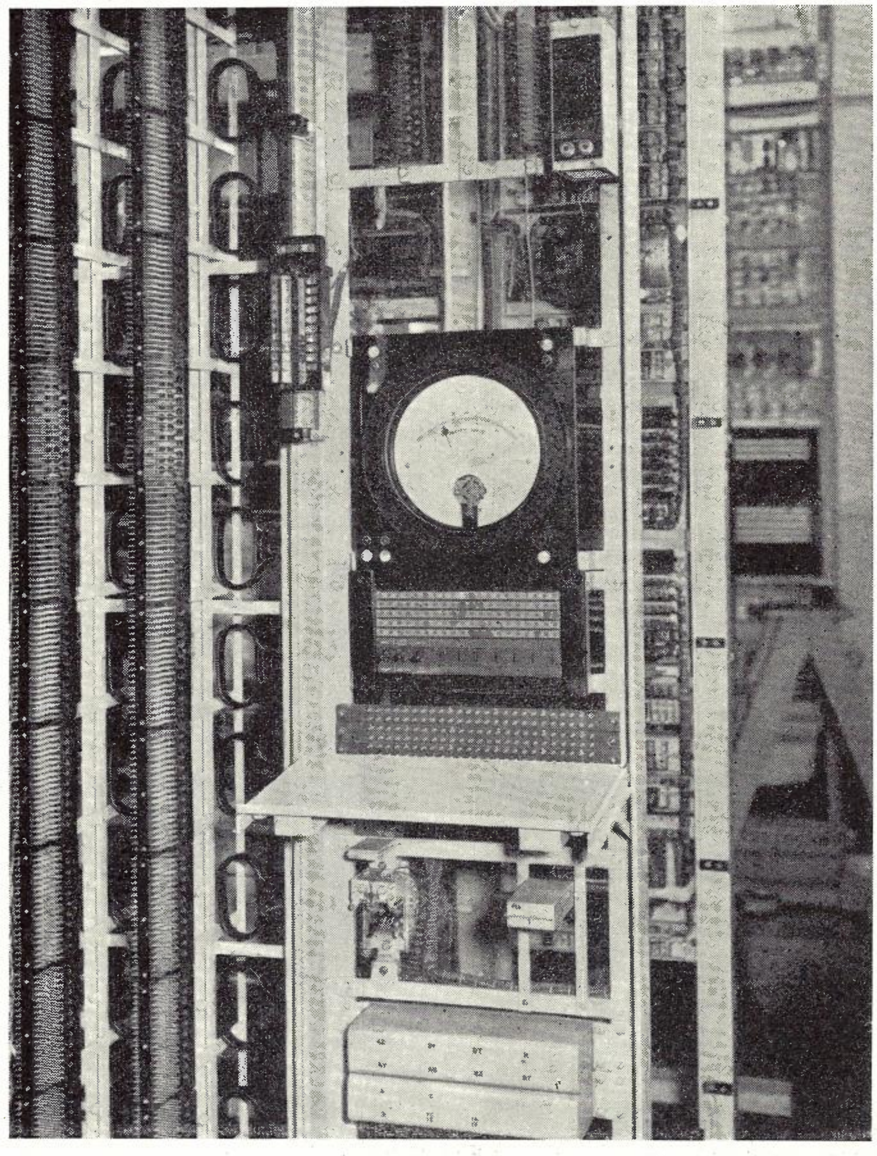


Fig. 4.—Resistor type traffic recorder control rack.

Control Rack

This is a 10 ft. 6½ in. x 1 ft. 6 in. rack, the upper portion of which consists of a terminal block assembly, while the lower part accommodates the meter, the lamps showing which group is connected to the meter, the operating keys, a collapsible table, a U link field, the access uniselector and all miscellaneous relays. The complete rack may be fabricated for not more than £200, and is the only part of the installation requir-

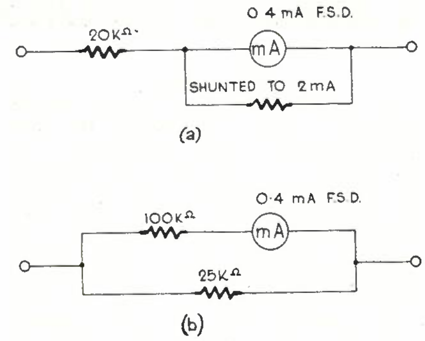


Fig. 5.

A circuit (Figs. 5a and 5b) has been developed which gives a form of T.U. scale which approaches the ideal, and is illustrated in Figs. 6a and 6b. The circuit arrangement of Fig. 5b is preferred to Fig. 5a as the meter movement is not damped so heavily. The combined resistance of the whole meter circuit has been made 20,000 ohms (this is for use with 1 megohm resistors) and it will be seen that this 20,000 ohm resistance has only a minor effect on low T.U. readings, but as more and more 1 megohm resistors in parallel are placed in series with the meter, it has a progressively greater effect.

If R = resistance of private resistors R_m = combined resistance of meter circuit and $K = R/R_m$, the choice of K governs the actual form of the meter scale. In this case a value of $K = 50$ was selected as being suitable, giving good accuracy over the range of readings to be used. The current I expressed in terms of the exchange voltage E, and R, R_m, and K, as defined above, and N, the number of resistors effectively in circuit, that is, the number of T.U.'s of traffic, is

$$I = \frac{E}{\frac{R}{N} + R_m} = \frac{E}{R\left(\frac{1}{N} + \frac{1}{K}\right)}$$

$$= \frac{ENK}{R(N + K)}$$

It will be seen that as N increases indefinitely, the value of I approaches a maximum of $I\ max = EK/R$. This is a useful feature since the meter is protected from serious overload if an earth fault occurs anywhere in the access and commoning arrangements, thus giving only a full scale deflection if the scale of Fig. 6a is used, or a 25% overload of the meter if the scale of Fig. 6b is used, and this is not serious.

This near ideal arrangement cannot be used where battery on the P wire (as opposed to open circuit) is the free condition. This condition occurs in

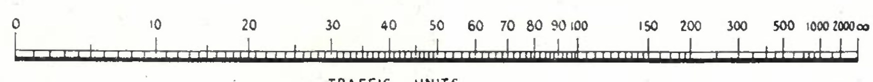


Fig. 6 (a).—Full meter scale 0-∞ T.U.

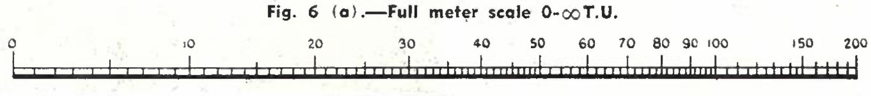


Fig. 6 (b).—Portion of meter scale used 0-200 T.U.

linefinders, and in any circuits with separate junction guard relays, for example, junctions to the main exchange where 2000 type D.S.R's to drawing CE.133 are used. In this case, all resistors on idle circuits are effectively in parallel with the meter, see Fig. 7, and

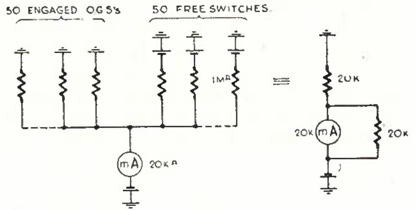


Fig. 7.—Effect on meter circuit of battery on the P wire as the free condition.

a considerable and variable error may thus be introduced. To obtain reasonable accuracy, the resistance of the meter circuit must be low compared with the effective shunting resistance, and must be in fact, of the order of 0.01% or less of the value of the individual private resistors. This completely rules out the arrangement arrived at above for any exchange where battery on the P wire indicates the free condition of any circuits, and, to date at least, no simple and easily reproducible non-linear meter arrangement has been found for a low resistance meter circuit. Under these conditions a two scale meter arrangement has been adopted, one of 50 T.U. full scale deflection, which gives good accuracy for most readings, and one of 200 T.U. full scale deflection to cater for the larger traffic groups. In order to minimise errors through use of the wrong scale, one scale is green and the other red and the range switching key also switches on a lamp of corresponding colour to indicate which scale is in use. The disadvantage of using two scales is appreciated, but this course was adopted in preference to only one scale, with the need to estimate readings to the nearest T.U., particularly on low readings such as analysis readings.

In this case in order to protect the meter against accidental earths on the commoning or strapping, a Carpenter relay has been included in the shunt circuit of the meter. In the event of an overload of more than 50% on either scale, the meter movement is open-circuited very quickly and the meter needle gives only a slight kick even if an earth fault is on the commons. The circuit arrangement is as shown in Fig. 8.

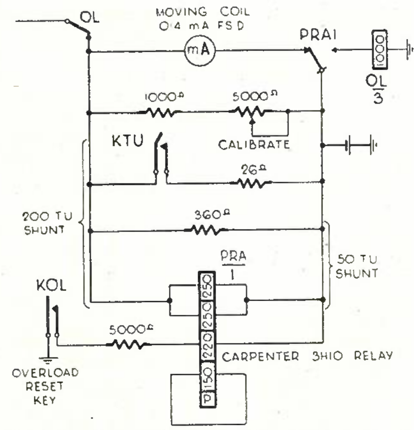


Fig. 8.—Use of Carpenter Telegraph Relay to protect the meter movement.

Analysis Arrangements

Provision has been made in the Unley exchange installation for analysis to be carried out by cutting straps and running a few additional jumpers at the control rack. This provision has not been made at Semaphore exchange, as local experience indicates that analysis is very rarely used, and it was considered easier to do the necessary re-strapping at the switch racks if analysis were ever required. If adequate mixing is used, analysis should not be required except at the first switching stage.

Following normal practice for analysis, the grading, for example, a small 4 group grading, is divided into 4 groups of individual switches with the remaining switches all grouped together in a 5th group. Each of these 5 groups is allotted a separate wire in the tie cable which loops into every rack of group selectors in that particular rank, and terminates on the control rack. The traffic recorder leads from the switches are commoned up as necessary on the traffic recorder block on the rack into these 5 groups. Each group is taken separately via the tie cable to the control rack, and on the control rack block, the 5 groups are strapped together, and a single wire jumper run from the uniselector bank terminal block to the terminal corresponding with the measuring position for that group. When analysis is required, the strapping on the tie block at the control rack is cut and extra jumpers run to spare positions on the uniselector bank block. If no positions were spare it would be necessary to use other positions temporarily, and analysis measurements would be taken separately from ordinary traffic measurements.

The principles involved are illustrated by relating all this to a hypothetical 4 group grading as shown in Fig. 9, and which may be considered for example to be between 2nds and 3rds in a small exchange. The grading itself is associated with the banks of the 2nd group selectors, but the outlets are 3rd group selectors and it is at the 3rds that the resistors are mounted and strapped. The 4 groups of individuals then will consist of,

AA1, AH1, BA1, BH1, AC2, AF2;
AB1, AG1, BB1, BG1, AD2, AE2;
AC1, AF1, BC1, BF1, AA2, AH2;
AD1, AE1, BD1, BE1, AB2, AG2;

and the 5th group will consist of,

BA2, BB2, BC2, BD2, BE2, BF2, BG2, BH2, AA3, AB3, AC3, AD3, AE3, AF3, AG3, AH3, BA3, BB3, BC3, BD3, BE3, and BF3.

These groups will be allotted 5 separate wires in the tie cable which will loop into racks A and B of 3rd group selectors and terminate on the traffic recorder control rack—for example, these wires could be 1, 2, 3, 4, and 5.

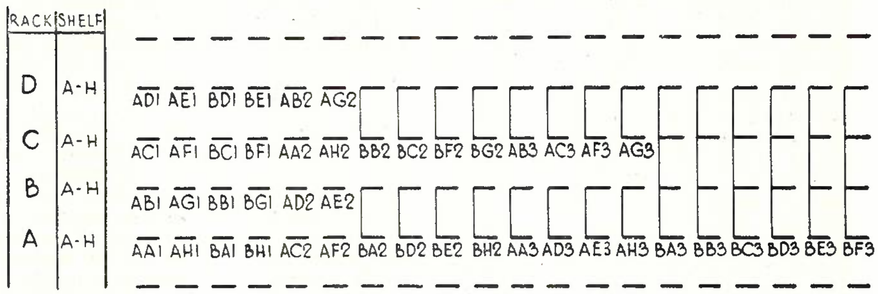


Fig. 9.—Hypothetical 4-group grading.

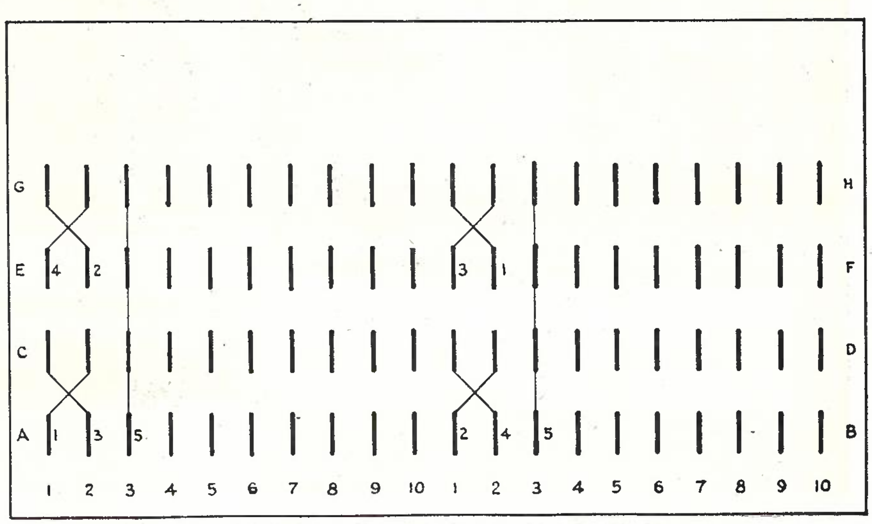


Fig. 10.—Traffic recorder strapping of rack A.

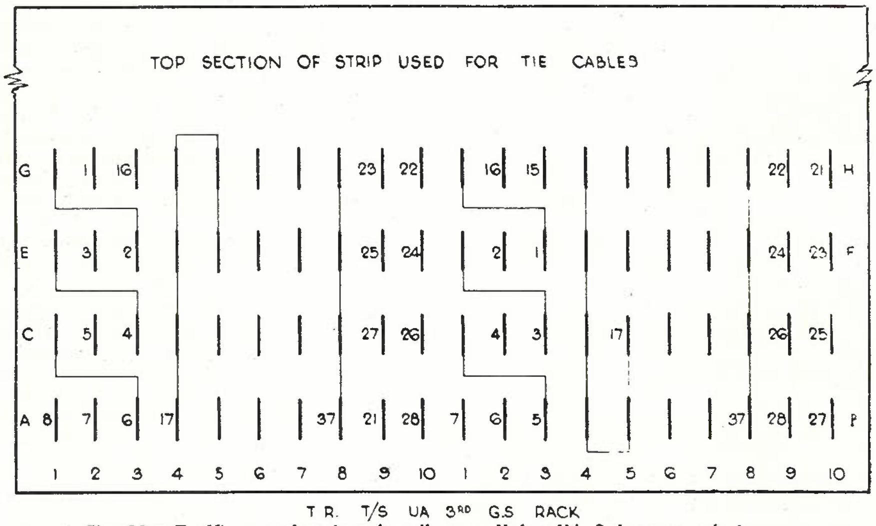


Fig. 11.—Traffic recorder strapping diagram Unley UA 3rd group selectors.

The commoning on the A rack would be as illustrated in Fig. 10, the number showing the tie to which the jumper would run. Commoning on the B rack would follow a similar pattern.

At the traffic recorder control rack, tags 1 to 5 on the tie block to 3rd group selectors would be strapped together and a single wire jumper run to the uniselector bank terminal block. If analysis were required, the only work necessary would be done at the control rack, the strapping between tags 1, 2, 3, 4 and 5 at the control rack being cut and four additional jumpers run to the uniselector bank terminal block to spare measuring positions.

Fig. 11 shows an actual strapping employed on one rack of 3rd group selectors in Unley exchange, and Fig. 12 is a photograph of the block concerned. In this case, the normal 20 x 4 T.R. block was replaced with a 20 x 10 flat 2000 type terminal block, and the tie cable (in this case a 63 wire cable) was terminated on the upper portion of the block.

Selection of Group to be Measured

In order to select and readily step over the various groups of resistors, a uniselector mechanism has been used to connect the particular group required to the meter as shown in Fig. 4. Provision has been made for up to 99 separate traffic groups, and a lamp field has been provided to show which particular group is connected to the meter. The uniselector may be stepped manually as required, or automatically at 6 second intervals, and may be returned to normal from any position.

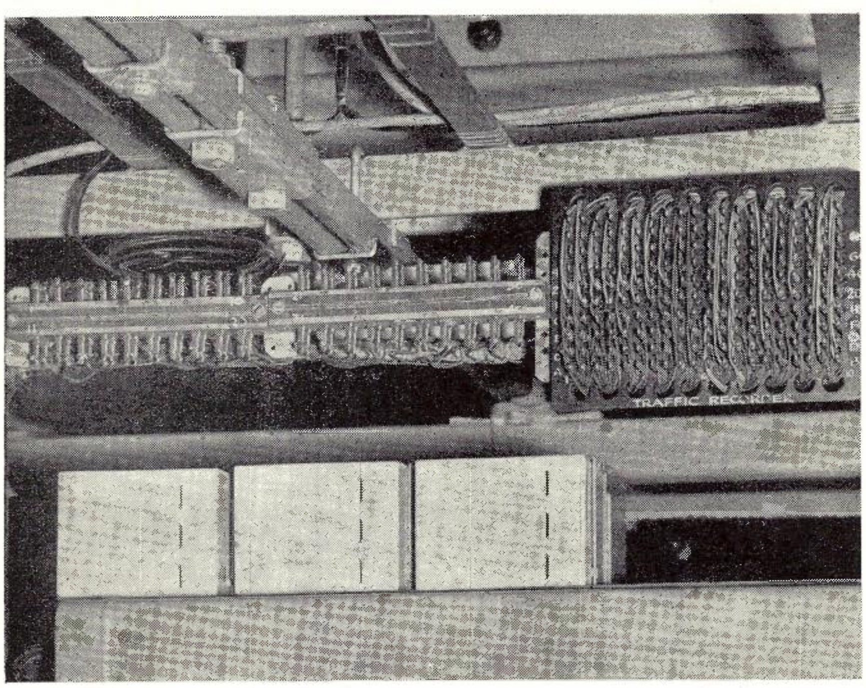


Fig. 12.—Traffic recorder strapping block Unley UA 3rd group selectors.

Test Set

Experience indicates that mistakes are sometimes made in traffic recorder commoning, or that traffic arrangements are overlooked in installations or rearrangements in exchanges. A test set has been designed therefore which allows a check to be made before recording commences, that every switch is in its correct group. This test, which also checks whether the recording resistors are within prescribed tolerances, may be carried out by one man working from the front of the racks. Fig.

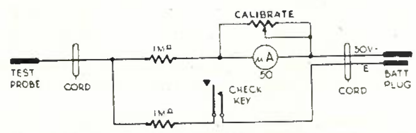


Fig. 13.—Circuit of traffic recorder test set.

13 shows the circuit and Fig. 14 the photograph of the test set.

An earth is placed on the common of a particular group at the control rack and the test probe is applied to the P on the test jack of each switch which should be in that group. The reading on the meter of the test set indicates whether the switch is commoned in that group, and whether the value of the resistor is within the allowable tolerances. It is necessary for this check to be done in a light traffic period, otherwise a switch which is not in the correct group, that is, the group with an earth on the common, could give a correct reading provided enough switches (say 10 or more) were busy in the group in which it appeared. It is envisaged that this test would be done at night some two weeks prior to the date on which traffic measurement were due to be taken in an exchange, in order that any strapping errors or fault conditions could be cleared before measurements began.

Measuring Procedure

The measurements are recorded in such a way that all recording and calculating work may be done directly on the one form, and no transferring of differences, totals or results to another form is necessary. A specimen sheet for part of the readings at Semaphore exchange is included in Fig. 15. The officer taking the reading will record each reading in the appropriate place, and at the end of the whole measuring period it is necessary only to add the columns, select the busiest hour on the totals, add this group of readings, and then divide by the product of the number of days in which readings were taken and the numbers of readings per hour: in the case of Semaphore this factor was 30. For the complete Semaphore traffic measurement taken in May, 1954, the whole of the computation, once the results were recorded, took 32 minutes; Semaphore is a 1700 line D.S.R. branch exchange and 11 traffic groups were measured. It might be mentioned that readings were taken on only 5 days in this case mainly because only limited manpower was available for traffic measurements; it is considered preferable to take readings over a longer period.

The rate at which measurements may be taken will vary with the damping

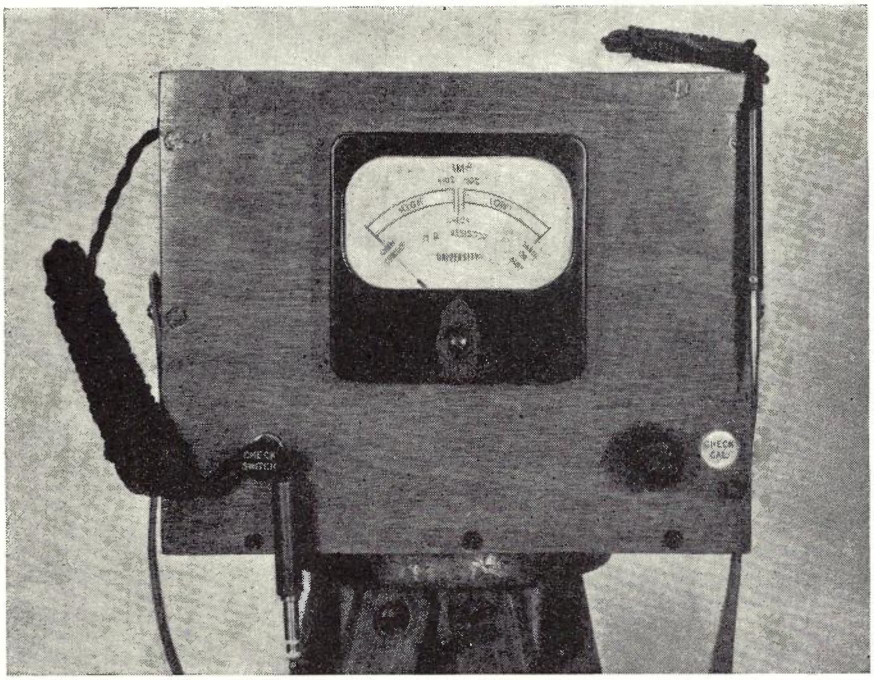


Fig. 14.—Traffic recorder test set.

characteristics of the meter and meter circuit used, and the frequency with which any particular group will be sampled will vary as well with the size of the exchange. It will be shown in the section on accuracy that even readings at intervals of 15 minutes will give acceptable results.

In general, readings are taken over an extended period for the first two days to show the trend of the busy hour in the various groups, and from then on measurements are taken only over a much shorter period of say 2 to 2½ hours around the busy hour. The actual method to be adopted in making measurements and in the processing of the data is, in the final analysis, a policy decision, but the above represents current South Australian practice.

Accuracy of Traffic Recorder Measurements

It would appear at first sight that if readings were taken at say ten minute intervals, that is, six readings per hour, the accuracy obtained would necessarily be much poorer than with the standard recorder which scans the measured groups 100 times per hour. An article by W. S. Hayward in the Bell System Technical Journal (March, 1952) however throws interesting light on this particular question. First it is necessary to distinguish clearly between (a) source load and (b) carried load.

Considering a given traffic source in which the general controlling factors are kept constant, the average busy hour traffic originated over a long period of time is the "source" load, and will be designated A. This is the quantity referred to in Erlang's formula, that is, "the average traffic of many busy hours", and is the quantity which is required for planning and for service checking.

The busy hour traffic on any particular day is not necessarily A, since it varies from day to day in a random manner. The actual busy hour traffic on a particular day is the carried load for that day and will be designated A′. Various assumptions are made in the analysis by Hayward, and, without detailing them, it is sufficient to say that they are admissible when applied to our methods of recording.

Considering first the accuracy of the estimate of "carried" load, the coefficient of variation given by Hayward and expressed as a percentage is:

$$V_x \simeq 100 \sqrt{\left\{ r \coth\left(\frac{r}{2}\right) - 2 \right\} \frac{\bar{t}}{A'NT}}$$

if $rc > 20$, that is $\frac{T}{\bar{t}} > 20$

Where r = ratio of scan interval to holding time
$\bar{t}$ = average holding time
A′ = carried load in T.U.s
c = number of switch counts per observation period
T = length of the observation period
N = number of observation periods.

If hourly observation periods are used, the condition $rc = T/\bar{t} > 20$ is not strictly applicable if the average holding time per call is 3 minutes or greater,

RESISTOR TRAFFIC RECORDER.

SEMAPHORE EXCHANGE. MEASURMENTS TAKEN FROM 30-4-54 TO 6-5-54.

GROUP	DATE	TIME OF MEASUREMENT.												B.H. AGG^{TE}	TU
		9·05	9·15	9·25	9·35	9·45	9·55	10·05	10·15	10·25	10·35	10·45	10·55		
D.S.R's. GROUP 1	FRI. 30/4	8	10	6	13	13	10	9	9	12	10	10	9		
	MON 3/5	4	9	10	6	7	7	10	9	9	5	6	4		
	TUES. 4/5	7	16	9	9	12	8	8	13	11	9	11	8		
	WED. 5/5	10	14	13	11	8	10	10	7	9	9	8	8		
	THUR 6/5	8	11	12	12	5	5	9	8	4	11	8	7		
		37	60	50	51	45	40	46	46	45	44	43	36	292	9·7
D.S.R's. GROUP 2	FRI. 30/4	11	10	17	14	12	8	12	9	9	9	10	7		
	MON. 3/5	14	14	5	10	13	9	5	6	13	13	10	9		
	TUES 4/5	8	11	12	12	16	10	10	5	11	20	12	12		
	WED. 5/5	8	17	13	14	8	14	10	11	12	8	8	6		
	THUR. 6/5	9	14	16	10	12	13	7	11	14	11	15	12		
		50	66	63	60	61	54	44	42	59	61	55	46	354	11·8
D.S.R's. GROUP 3	FRI. 30/4	5	8	7	11	16	14	9	10	9	6	5	7		
	MON. 3/5	9	6	12	11	9	9	13	8	9	7	8	9		
	TUES. 4/5	8	13	11	10	10	10	15	6	10	10	7	6		
	WED 5/5	5	6	10	10	12	11	8	9	13	4	8	8		
	THUR. 6/5	6	10	12	8	8	9	8	10	8	5	3	6		
		33	43	52	50	55	53	53	43	49	32	31	36	306	10·2

SIX CONSECUTIVE READINGS GIVING HIGHEST AGGREGATE SHOWN THUS :-

Fig. 15.—Specimen sheet of traffic measurements at Semaphore Exchange, South Australia.

which would probably be the case in some suburban exchanges at least. However, even if the average holding time per call were as long as 6 minutes, (there is no such case recorded in South Australia), the error estimate obtained by using the above formula would be 0.85 of the true error, that is, error estimate is not seriously affected.

When $r \leqslant 2$, that is, when the measuring interval is 6 minutes or less for an assumed holding time of 3 minutes, the error formula simplifies to

$$V_x \simeq \frac{100}{c/T} \sqrt{\frac{1}{6A'NT}} \%$$

The error in the estimate of carried load will therefore be inversely proportional to the scanning rate in cycles per hour. Hence, as one would expect, the standard recorder gives a much more accurate estimate of the carried load than the resistor recorder.

The same is not true, however, in relation to the estimate of the source load which is made from several of these carried load estimates. The coefficient of variation in this case is

$$V_s = 100 \sqrt{\frac{\bar{t}}{ANT} r \coth \left(\frac{r}{2}\right)} \%$$

The accuracy of estimate of source load is, therefore, proportional to $\sqrt{r \coth \left(\frac{r}{2}\right)}$ so far as variation of scanning rate is concerned. The graph, Fig. 16, shows the variation of this

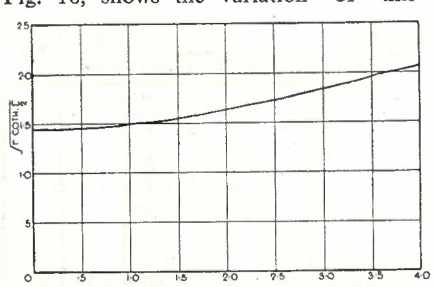


Fig. 16.—Graph of function $\sqrt{r \coth r/2}$

function in relation to r, that is, the variation with varying scanning rates, and indicates that no very serious loss in accuracy in estimating source load results from decreasing the number of scans per hour from 100 ($r = 0.2$) to 6 ($r = 3\frac{1}{3}$). Fig. 17 shows a comparison of errors to be expected with straight switch count methods in estimating source load with a half-minute scan interval, compared with a 10 minute scan interval, and emphasises the point that the scanning rate has small effect on the estimate of the source load.

The number of observation periods, however, has a much more pronounced effect on the accuracy of the estimate of source load, the error being inversely proportional to $\sqrt{N}$. The standard recorder is designed in such a way that it is normally necessary to take three separate sets of readings to completely cover an exchange. This in itself is a serious disadvantage (which the resistor

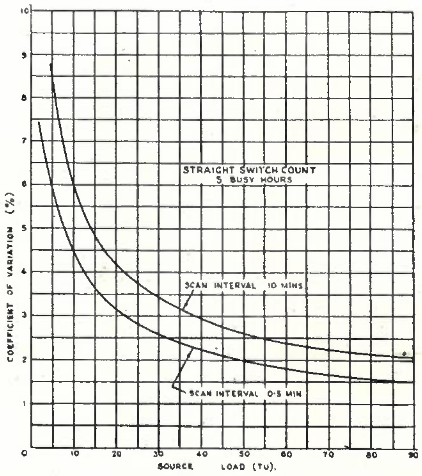


Fig. 17.—Comparison of accuracy of estimate of source load—½ and 10 minute scan intervals.

recorder overcomes) but in addition it is possible with the resistor recorder to take readings for all groups over three times the number of observation periods, in the same overall time with a corresponding increase in accuracy.

It is also necessary to consider the random variation in value of the resistors used in the resistor recorder, which introduces an error which could be of controlling magnitude. This error is limited in practice by using 2% tolerance resistors, and, as it is not correlated at all with the other errors considered, it may be combined with them by summing variances, giving an overall coefficient of variation

$$V_s = 100 \sqrt{\frac{\bar{t}}{ANT} r \coth \left(\frac{r}{2}\right) + T_R^2} \%$$

where T_R is the coefficient of variation of the resistor used. Fig. 18 shows the likely error using the resistor recorder compared with that to be expected with the standard recorder,

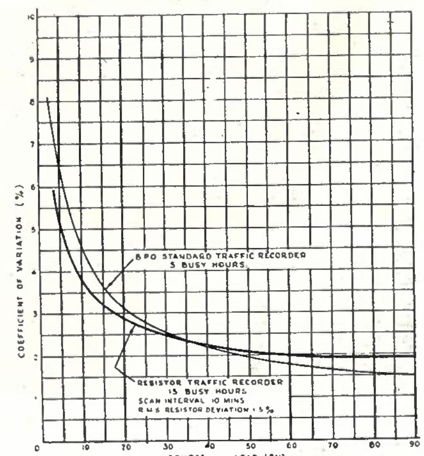


Fig. 18.—Comparison of accuracy of B.P.O. and resistor traffic recorders.

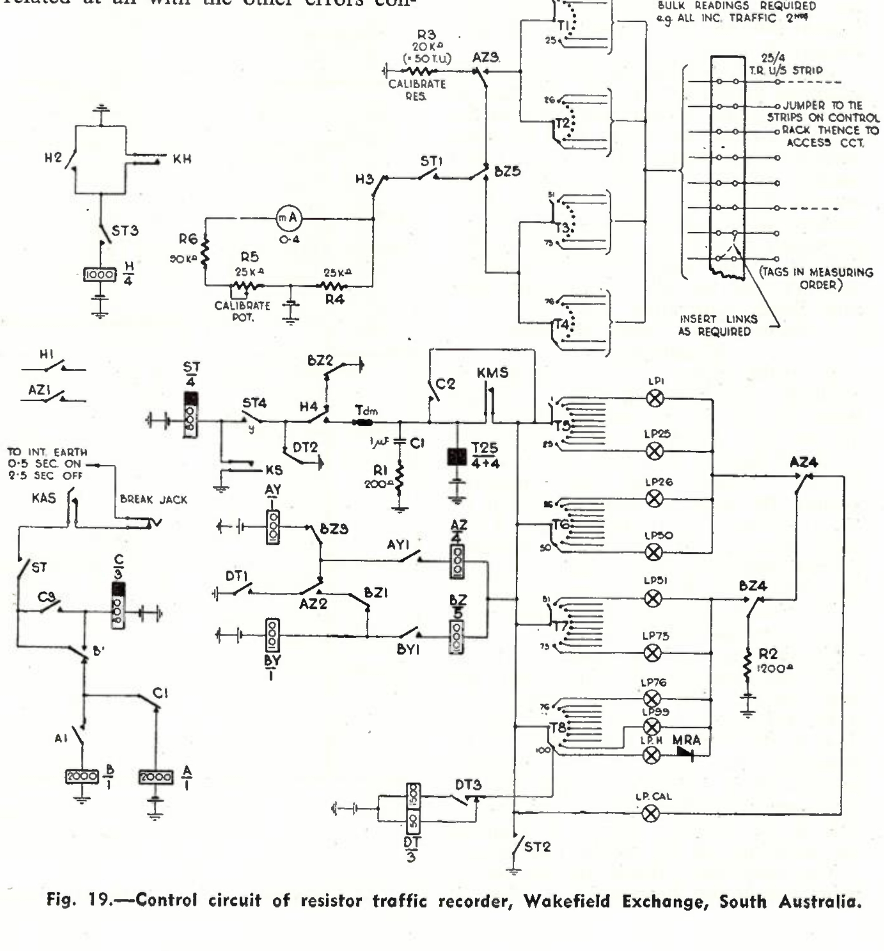


Fig. 19.—Control circuit of resistor traffic recorder, Wakefield Exchange, South Australia.

assuming that the coefficient of variation of the resistors is 1.5%, and allowing 3 weeks overall for readings in each case.

Size of Resistors

Although one megohm resistors have been used at Unley and Semaphore exchanges, these tend to drift high in value over a period of years, and for this reason it was planned to use 10,000 ohm resistors at Stirling exchange, and it was anticipated that a much better long term stability would be obtained in this way. This value, however proved to be too low as it interfered with the release of the switch trains on the release unguard, and 20,000 ohms probably represents the lowest practicable value of the resistor. For future installations it is at present planned to use 100,000 ohm resistors.

Use in Smaller Exchanges

In small exchanges and P.A.B.X.'s it is proposed to install the resistors permanently, wiring the commons to a convenient point (for example on the M.A.R.), and use a portable recording set, which would be connected by running only one cable, or even by a suitable plug and socket arrangement. This method would reduce setting up time as compared with present portable recorders, and would allow effective readings to be made quickly with a minimum of interference with working equipment and without providing a permanent traffic recorder control rack.

Circuit Used

Fig. 19 shows the circuit used for the traffic recorder control rack at Wakefield exchange. As the installations mentioned have been more or less developmental, there are minor variations in the circuits used in the various exchanges, but this circuit is typical.

Conclusion

After a comparatively short period of field use, it is considered that the results obtained have more than justified the developmental effort. Further improvements have suggested themselves, and it is also envisaged that extension to an automatic recording system will ultimately be made using this recorder as a basis.

AN UNUSUAL OPERATION IN MULTI-DUCT PROVISION

I. McDOWELL, B.A., B.Sc.

The route chosen for the provision of 18 ducts between City West and South Melbourne in the Melbourne network traverses a large area of concrete paving at a service station. The proprietor objected strongly to the proposal to cut the surface to allow the usual practice of trenching to proceed.

Fortunately, a disused 30-inch diameter cast iron gas main was found to exist along the route at this point. With the approval of the Gas and Fuel Corporation, this main was utilised to carry the ducts. Thus the inconvenience of opening the concrete paving, together with difficult operations in unstable soil and costly reinstatements, were avoided.

Two manhole sections, using approximately 80 yards of the main, were involved, and to expedite handling of material in the unstable ground, the manholes were constructed at the outset. Fibro-cement pipes 13 feet long of 4 inch inside diameter were employed. For jointing, plastic collars were obtained which were flush with the outside of the pipes when joints were made. See Fig. 1.

After cleaning the main, a drain was laid at the bottom, followed by 9 inches of packing sand introduced and surfaced with a sledge. On this surface, flat and corrugated fibro-cement sheets were provided such that the flat sheets were underneath, and the butt joints in the flat sheets occurred at the mid-points of the corrugated sheets and vice versa. These were rivetted together to provide a firm rigid bed for the pipes. See Fig. 2.

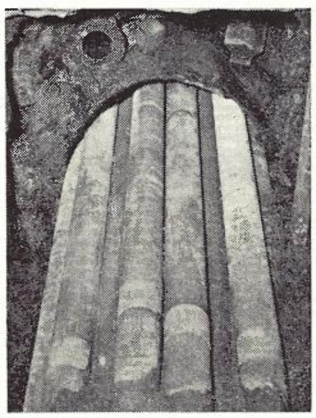


Fig. 1.—The pipes at one end of the main. Part of this particular section was in open trench. Note the flush-fitting collars.

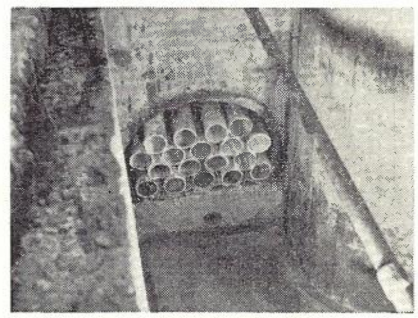


Fig. 2.—The ducts entering one of the manholes, prior to sealing off the main. Note the fibro-sheet base.

The pipes were drawn one at a time by hand winch into the main; the bottom layer resting in the corrugations of the fibro-sheet, and the higher layers resting in the grooves formed by the lower layers. On completion of the operation the ducts were tested and formed into the manholes so that the main could not be seen.

MR. A. R. CAMERON

MR. A. R. CAMERON

In January 1903, an historic event was being enacted in Australian History at the opening of the goldfields water supply to Coolgardie and Kalgoorlie, Western Australia. On that occasion, among the ceremonies, Sir John and Lady Forrest were drawn from Coolgardie Railway Station to the Coolgardie Exhibition by a team of boys dressed in sailor suits. Among these boys was one, A. R. Cameron, destined to fill the top Engineering post in the New South Wales Engineering Service in the Postmaster-General's Department.

Mr. Cameron, in his chequered career, has seen history unfold before him. Born at Whroo, Victoria, on 2/9/89 he was present at the "Turning of the first Sod" for the Trans Australia Railway Line. He entered the Postal Service when he was appointed Telegraph Messenger at Coolgardie, Western Australia on 1/6/1904. He began to make his mark in the Postmaster-General's Department and attained top marks in the Commonwealth Clerical Examination and second top marks in the Junior Engineer-in-Training Examination, also winning a Scholarship to the Kalgoorlie School of Mines. He then qualified as Junior Assistant Engineer and was appointed in this position to Perth on 1/10/14. Whilst a Junior Assistant Engineer, Mr. Cameron volunteered for war service and joined the 1st Anzac Wireless Squadron which served with the Indian Expeditionary Force "D" in Mesopotamia and Persia. He was a member of the Squadron's station which was attached to the 1st Caucasian Russian Army operating under General Baratoff in Persia for a period of nine months. He was mentioned in despatches by General Marshall for gallantry and distinguished service in the field. During his service overseas, he indulged to a great extent in his sketching and caricaturing and in the Land of Baghdad and the Caliphs this afforded an excellent opportunity for his talents.

On returning to Australia, Mr. Cameron was promoted to the position of base grade Engineer, Perth, and in this sphere he provided the first teletype machines between Perth and Kalgoorlie and Perth and Geraldton. He invented the "Y" repeater on the No. 2 side of the Quadruplex Telegraph which saved the services of two men. When a new telegraph line was provided along the Railway line between Port Augusta and Kalgoorlie, Mr. Cameron was responsible for installing the machine telegraph systems on this line and thus releasing the machine equipment from the old Eucla line.

In 1927 Mr. Cameron was appointed Divisional Engineer, Telegraphs, Workshops, Adelaide and remained there for eleven years. During this period he was in charge of the Overland Telegraph Line and equipment between Adelaide and Darwin and made many trips along this route. At Darwin telephone switchboards and telegraph facilities were installed and at Alice Springs the work of removing the telegraph repeater station from the old original Alice Springs office to the new Post Office in the township was undertaken. Other power plants installed included Norseman, Eucla and Cook.

As a result of his interest in the Overland Telegraph line, Mr. Cameron produced the story of the line in book form. This serves as a historical record of the wonderful work of Sir Charles Todd and his men who built this line in 1872. During the Adelaide Centenary, Departmental exhibits designed and installed under Mr. Cameron's control won the centenary Gold Medal for the Department.

In 1938 he was promoted to the position of Supervising Engineer, Workshops, Sydney, soon after the commencement of the Second World War. This Workshops was required to produce considerable quantities of signalling equipment for the Armed Forces and telecommunication equipment to the value of £2,000,000 was manufatcured under the management of Mr. Cameron.

Mr. Cameron was appointed Deputy Superintending Engineer in June, 1950, and has occupied the position of Superintending Engineer since 23/7/53.

It is very natural to assume that so colourful a character would be absorbed in hobbies designed to gentle living and broadening and enriching of the mind and so we see the caricaturing bend previously referred to, being developed through the years in line with artistic work in water colours. An inspection of this work at the Exhibition Galleries where they have been displayed shows up Mr. Cameron as an artist above the status of amateur. He has always been a keen sportsman equally at home on the golf course, the bowling green or running before a stiff breeze in a sailing craft.

All in all, Mr. Cameron is a man to whom we can all look upwards. A broad man, developed socially, on the sporting field and

"In the world's broad field of battle,
In the bivouac of life,"

he had always that personal interest in the welfare of his staff. His voice was always raised in encouragement and assistance to Departmental staff activities and his humour with its salty pleasantry, gave life to many a social gathering which was pleased with his chairmanship. In truth he followed Longfellow's advice to

"be a hero in the strife!"

ANSWERS TO EXAMINATION PAPERS

The following answers generally give more detail than would be expected in the time available under examination conditions. The additional information should be helpful to students.

EXAMINATION Nos. 3963 and 3964. TECHNICIAN, RADIO AND BROADCASTING

J. K. Smith.

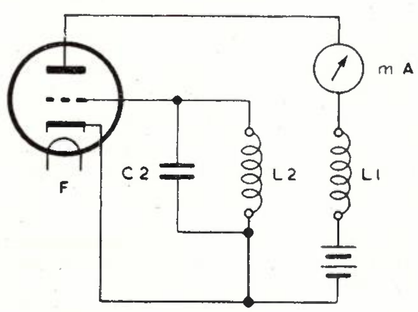
Q.3 (a) Name three means of generating an alternating current supply.

A.—Valve Oscillator. Generator. Vibrator.

Q.3 (b) Describe one of these methods in detail.

Valve Oscillator.

A.—(b). The operation of the valve oscillator is as follows: With the cathode heated and the high tension supplied, a current will flow from the plate through coil L1 to the cathode. The current through the coil gives rise to a magnetic field which cuts the windings of coil L2. The coil L2 is connected to the grid in such a way that the induced emf in L2 swings the grid more positive. The plate current therefore increases, resulting in a greater expansion of the magnetic field in the same direction around L1 and consequently the grid swings still more positive. This action continues up to a point depending on valve characteristics and resistance of the circuit.

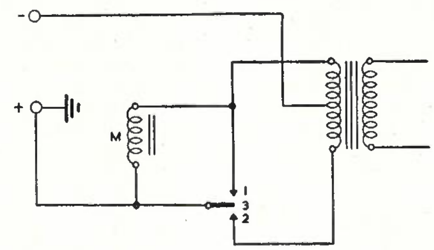


Q.3—Fig. 1.

When the rate of change of anode current starts to decrease it results in a lowering of the grid potential, because the induced emf in L2 is dependent upon the rate of variation of current through coil L1. This effect causes a further decrease in anode current. The magnetic field around L1 therefore collapses and the emf induced in coil L2 is such as to reverse the grid potential. This continues until the rate of change of anode current again decreases due to valve characteristics and circuit resistance. Thus the anode current rises and falls at a definite frequency, the period of which is dependent upon the values of L2 and C2 in the circuit. See Fig. 1.

The Vibrator.

Current flow from the battery passes through the upper winding of the primary and through the energising magnet M. This energises the magnet and shifts the armature 3 to contact 1. A large current flows in the upper half of the primary winding. Electromagnet M is shirt circuited and the armature restores, carries over to terminal 2, and a large current flows in the lower half of the primary winding. By this time the magnet will be re-energised and the cycle continues.

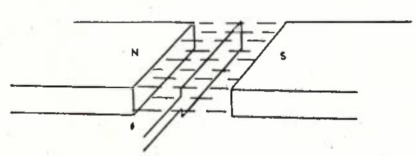


An alternating potential is induced in the secondary the magnitude of which depends on the ratio between the primary and secondary turns and upon the low tension current.

A.C. Generator.

A basic generator consists of a number of turns of wire made to rotate in the field of a permanent magnet.

The current flow in the loops of wire, produced by the induced e.m.f., changes direction everytime the plane of a loop passes through the vertical position. In the vertical position the loop of wire is cutting a minimum number of lines of force while in the horizontal position a maximum number of lines of force is



cut. The direction of current flow in the rotating conductor depends on the "Right Hand Rule". The forefinger follows the direction of the lines of force, the thumb is in the direction of motion of the loop and the index finger indicates the direction of current flow in the conductor.

Connection is made to the machine by means of "Slip Rings" and "Brushes". The armature is the part in which the e.m.f. is generated, the field can be supplied by permanent magnets or by electromagnets.

Q.4 (a) What do you understand by the term "power rating of a resistor"?

A.—A resistor in an electrical circuit dissipates energy in the form of heat, and it is convenient, therefore, to rate the resistor according to the heat or power that it can dissipate safely. Resistors are rated by the number of watts they can dissipate and this depends almost entirely upon the surface area and the method of construction of the resistor. The maximum number of watts which can be safely dissipated continuously in the resistor is the "power rating".

Formula for wattage calculations

$$\text{Watts} = I^2R,\ E^2/R \text{ or } EI.$$

Q.4 (b) What factors in the design of a wire-wound resistor affect the power rating?

A.—The factors affecting the heat dissipation of a wire-wound resistor are the size and type of core on which the resistance wire is wound, the gauge and material used of resistance wire and the insulation between turns.

Q.4 (c) What further considerations must be taken into account if the wire-wound resistor is to be used for radio frequencies?

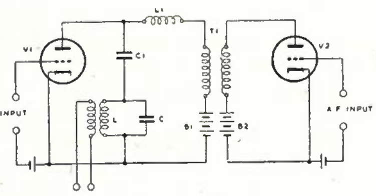
A.—For wire-wound resistors at radio frequencies the inductive and capacitive effects of the winding must be considered. The inductance is determined primarily by the number of turns of wire and the area enclosed by the individual turns. Therefore, to keep the inductance low, the area enclosed by each turn should be a minimum and the wire should have as many ohms per foot as possible, so that the total length will be small. It is usual for adjacent turns to be wound in opposite directions so that any residual inductance of a particular turn is neutralised by that of an adjacent turn. The capacitive reactance is kept small by arranging the windings so that adjacent turns have a low potential difference between them and are as far apart as possible.

Q.4 (d) Describe the construction of one type of radio frequency wire-wound resistor.

A.—The Ayrton-Perry type of resistor is constructed by winding a spaced layer of insulated wire on a thin strip; then a second wire is wound on the strip in the opposite direction between the turns of the first winding. The two windings are connected in parallel and produce practically zero resultant magnetic effect. The distributed capacity is low because adjacent turns have very little potential difference between them.

Q.5.—Explain, with the aid of a simple circuit and operating characteristics how a triode radio frequency amplifier may be used to plate modulate the radio frequency energy.

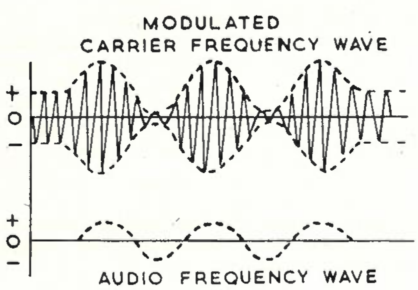
A.—For an R.F. amplifier to be used as a modulated amplifier it must be adjusted to work as a linear class C R.F. amplifier. A class C amplifier is one in which the plate current flow is restricted to less than 180°, generally to about 120°. A tuned circuit is used as the plate load and this restores the pulses of energy to essentially sinusoidal form. The basic circuit of a plate modulated class C amplifier is shown in Fig. 1.



Q.5—Fig. 1.

The valve V1 is adjusted so that with no audio frequency input signal it operates as an ordinary class C amplifier with the bias at least twice the cut off value for the plate supply voltage. When the audio signal is applied then the plate supply voltage to valve V1 is made alternatively more or less positive in accordance with the voltage developed across the secondary of transformer T1. Assume that for the first half of the audio wave this secondary voltage assists the battery voltage B1 and that the plate supply voltage is eventually doubled. With the total plate voltage doubled, the plate current is doubled, because the valve is operating under linear class C conditions. On the next half cycle of the audio wave the voltage developed across T1 opposes that of the battery potential B1, the total plate supply voltage is zero and hence the anode current is zero.

Fig. 2 illustrates the effect of modulating the audio frequency wave on the carrier frequency.



Q.5—Fig. 2.

Q.6.—Explain fully the terms—

(a) primary service area,

(b) secondary service area,

in considering the coverage provided by a medium frequency broadcasting station.

A.—The propagation of medium frequency radio signals during daylight hours takes place by means of a wave along the surface of the ground (ground wave). The further the distance this wave travels from the radiator, the weaker it becomes due to earth losses and spreading.

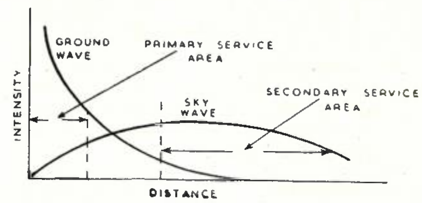
At a distance of about 60 miles above the surface of the earth is a conducting layer of ionised air particles which, under suitable conditions, bend a radio wave back to earth. During daylight, this effect is small, but at night the ionised layer causes the radio waves to be refracted back to earth (sky wave).

There are thus two components of the transmitted wave present at the receiving point during night time conditions—

(1) Ground wave along the surface of the earth.

(2) Sky wave refracted from the ionosphere.

Close to the transmitter the ground wave is the dominant one, while at large distances the sky wave is the stronger. At some intermediate distance, the two waves are of approximately equal amplitude, and the resultant field depends primarily on their phase relation. Further, the ionosphere conditions continually vary, causing this relative phase to vary. Consequently, the resultant signal in the region where the ground and sky waves are approximately equal, usually suffers severe fading with accompanying distortion.



Q.6—Fig. 1.

The area close to a medium frequency broadcasting transmitter in which the ground wave is relatively strong as compared with the sky wave, and where the received signal is not subject to objectionable interference or fading, is called the Primary Service area. This area is sometimes defined as the area in which less than 50% fading occurs, and is determined arbitrarily as follows:—

Per cent fading

$$= \frac{\text{mean signal value - minimum value}}{\text{mean value}} \times 100$$

A typical field strength figure said to provide a primary service in a residential area is between 2 and 10 mV/metre.

Beyond the primary service area, the received signal is subject to severe fading due to the interaction of ground and sky waves mentioned previously.

The Secondary Service Area is the area served by the sky wave (beyond the influence of the ground wave), and not subject to objectionable interference. The signal is, however, subject to fading. This area is sometimes defined as the area where the sky wave for 50% or more of the time has a field intensity of 0.5 mV/meter or greater. Fig. 1 shows these conditions.

Q.7.—Describe fully the precautions necessary for replacing a high power, hot cathode mercury vapour rectifier valve in a transmitter rectifier circuit.

A.—A mercury vapour rectifier contains a small amount of metallic mercury which vaporises when heated as the cathode temperature is raised. When a potential difference exists between anode and cathode the vapour is ionised and the positive ions produced move to the cathode and neutralise the space charge. Maximum current is then available for a minimum P.D. across the rectifier.

If the high tension were applied at the same time as the heating voltage then damage to the cathode of the valve could result. The few positive ions that become available as the gas vaporises are subject to as high a P.D. between anode and cathode as that of an ordinary vacuum tube. This will give the positive ions of gas produced a velocity high enough to disintegrate the cathode by bombardment. It is necessary, therefore, that the heater volts are applied at least 30 seconds before the high tension. A manufacturer may specify longer for a new rectifier valve.

A certain heating time is also needed to vaporise and clear the mercury which may be "spattered" over the elements of the valve.

It is also desirable that these valves be taken from a store where the temperature is maintained at a normal room rating. This factor avoids extreme temperature changes when the valve is placed in service.

Q.8. (a) Explain the terms "Unidirectional", "Bidirectional" and "Cardioid" as applied to directional microphones.

A.—The "Pick Up" area of a microphone is referred to as the directional characteristic pattern of reception.

A unidirectional pattern is where a particular microphone is located to receive energy from one direction.

A bidirectional pattern is where energy can be received from two directions.

A cardioid pattern is heart-shaped and serves to eliminate undesired background noises.

Q.8 (b) Under what circumstances would each of the above characteristics be used?

A.—A unidirectional microphone, fitted with a baffle, would make an ideal announcer's studio microphone. It could also be used for sports commentaries and as a communication microphone between studio and control booth.

A bidirectional microphone achieves its chief uses as an interview, small play, piano and soloist, microphone.

The cardioid microphone can be used in play productions, orchestral or dance band work where extraneous crowd noise or background is undesired.

Q.8 (c) Describe briefly a microphone which provides all three directional characteristics.

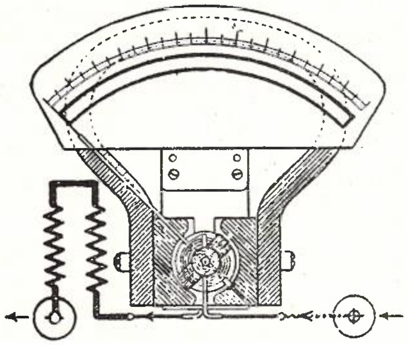
A.—A microphone which combines all these features is the cardioid microphone. Basically it consists of a moving coil and a ribbon type microphone in a common housing. It has a three-position control by which any one of the three directional characteristics can be obtained. In the third position the two microphones are electrically connected and the directional characteristic is the combination of the moving coil and ribbon type microphone characteristics. The pattern is unidirectional of heart-like shape, hence the name cardioid.

Q.9.—Describe briefly the construction and operation of the following meters.

(i) Moving coil voltmeter.

(ii) Electrostatic voltmeter.

(iii) Thermo-couple ammeter.



MOVING COIL INSTRUMENT AS A VOLTMETER.

Q.9—Fig. 1.

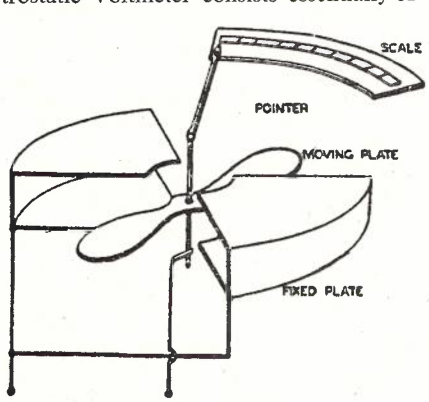
A.(i)—A Moving Coil Voltmeter consists essentially of a simple moving coil meter movement together with a large resistor in series.

A moving coil meter is shown in basic construction. A light coil of fine wire is wound on an aluminium former is free to rotate and is located between the poles of a permanent magnet. The springs located at each end of the moving coil serve to supply the current and return the coil to the zero position.

The use of an aluminium former assists in producing a feature termed "Eddy Current Damping". This prevents overswinging or "light" pointer movement.

The meter scale is evenly divided as the deflection is proportional to the current flowing. The meter reads Direct Current or rectified Alternating Current.

(ii) Electrostatic Voltmeter. The Electrostatic Voltmeter consists essentially of

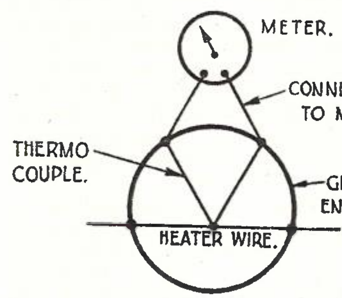


Q.9—Fig. 2.

two plates or vanes, one fixed and the other free to rotate. A pointer is attached to the moving vane.

The meter depends for its operation on the electrostatic attraction between the vanes when the voltage to be measured is applied. The meter reads D.C. or R.M.S. values of Alternating Current. The meter is used to read high voltages at radio frequencies.

(iii) Thermo-couple Meters. These meters depend for their operation on the effect of heating a junction of two dissimilar metals and a measurement of the voltage produced is indicated on a meter.



Q.9—Fig. 3.

As shown in the sketch, the source to be measured is connected to the heater and raises the temperature of the junction of the two metals (Bismuth and Tellurium), the open ends are connected to the meter. The meter scale is naturally calibrated in accordance with the current flowing in the heater. The scale is calibrated in R.M.S. amps. The meter can be used to read high frequency currents.

Q.10 (a) What is meant by the reverberation time of a studio?

A.—A sound produced in an enclosed space, for example, a studio, is reflected back and forth from the walls, floor, and ceiling. The persistence of the sound due to these repeated reflections is called reverberation.

A portion of the sound energy is absorbed at each reflection, until its intensity is so reduced that it becomes inaudible. The rate of decay or fading in the sound power level can be measured at any point in the room over a given period of time. The time (in seconds) taken for the average sound energy, emitted at a steady rate and at a given frequency, to decrease to one-millionth (60 db) of its initial value, after the source has stopped, is called the reverberation time.

Q.10 (b) What are the ranges of reverberation times which may be encountered in—

(i) an announcing studio,

(ii) an auditorium?

A. (i) 0.3-1.0 second. Small studios required for talks and plays are generally adjusted to have a reverberation time of 0.6 second, as at this value, the effect of the reflected sound is negligible, and maximum intelligibility is obtained.

(ii) Reverberation times of 1-2 seconds are encountered in auditorium studios; depending on the dimensions of the studio.

Q.10 (c) What constructional methods are used to obtain a particular reverberation time?

A.—The reverberation time of a studio is controlled by its dimensions and shape and the materials used at the boundaries, and these can be altered to obtain a particular reverberation time. To avoid excessive reverberation time it is usual to resort to such devices as avoiding the use of panel walls and not having the ceiling parallel with the floor. In addition, the walls and ceilings may have curved sections in the convex manner. The wall surfaces are lined with sound absorptive materials. The greater the surfaces covered with sound absorbing material, the lower the reverberation time.

EXAMINATION No. 3942—SENIOR TECHNICIAN, TELEPHONE. TELEPHONY 1.

D. J. McConchie

Q.1.—In an automatic exchange the following Routine Tests are performed:—

(i) Off normal and permanents.

(ii) Alarm signal.

(iii) Subscribers' meters (registers) test.

(iv) Switch performance tests, group selectors.

(v) Tests on subscribers' services.

State briefly the reason for each test and also the frequency of the above tests.

A.—(i) Off Normals and Permanents.

Off normals and permanents is a test made to determine whether a conversation is in progress on each switch which is in an operated or off normal position. These tests are performed three times daily in the following sequence:

(a) Final Selectors for Off Normals.

(b) Repeaters for Permanents.

(c) Group Selectors for Off Normals and Permanents.

(d) D.S.R's or Selector Repeaters for Off Normals and Permanents.

(e) Final Selectors for Permanents.

(f) Bimotional Line Finders for Off Normals.

(ii) Alarm Signals.

This routine tests the various visual and audible alarm signals associated with the exchange equipment and comprises

(a) Release Alarms.

(b) Fuse Alarms.

(c) Supervisory Alarms.

(d) P.G. Alarm.

(e) N.U. Tone Supervisory Alarm.

(f) N.U. Tone Overload Alarm.

A proportion of the alarm signals in use in the exchange is checked each day for correct operation. The entire alarm signal equipment to be covered once weekly, urgent alarm signals to be checked daily.

(iii) Subscriber's Meters (Register) Test.

This test is performed to ensure the correct operation of the subscriber's meter, and if faulty, to give some indication of possible causes of the incorrect operation.

Ten operate tests and one non-operate test are applied to the register. On completing the test the reading of the register should be checked to determine whether ten operations have taken place. This routine test is performed twice yearly.

(iv) Switch Performance Tests, Group Selectors.

In this routine test the impulsing, cutting in, switching, holding and releasing function of group selectors are tested.

Each group selector should be tested twice weekly, a different level being used for each test, so that the cut in of wipers on each level will have been tested at the end of ten tests. In the case of a faulty incoming selector the distant exchange should be notified so that the circuit may be busied in the distant exchange.

(v) Tests on Subscribers' Services.

This routine test should be performed once a year on each subscriber's line connected to the exchange. Care must be taken to perform this test in conjunction with the sub-station faultman where the services are either Cordless P.B.X., services provided with local battery, or cord type P.B.X's.

The routine test record should indicate the services to be tested; such test to be performed at the time of light traffic. The test should include:

(a) Correct operation of L and K relays.

(b) Insulation resistance of the subscriber's line.

(c) Conductor resistance of the subscriber's loop.

(d) Speed test and impulse ratio test of the dial.

(e) Transmission test.

(f) Check on cable pair.

Q.2.—With any type of two party line, including duplex services, in which two subscribers with individual numbers are connected to any type of automatic exchange on one pair of wires. Describe briefly:—

(a) The additional equipment necessary and the main functions of such equipment—

(i) at the exchange;

(ii) at the subscriber's premises.

(b) Why it is necessary to pay particular attention to the earth connexion at the subscriber's premises.

A.—(a) In the case of a duplex service in which two subscribers have individual numbers, the functions of the additional equipment at the exchange are—

(i) (a) To extend the calling party's line to the calling equipment.

(b) To prevent the non-calling party looping the calling equipment, this being achieved by removing battery from the line. The removal of battery from the line occurs when an earth potential from the first rank of biomotional switches is applied to either the LC or LD relays.

(c) To busy the non-calling party to any incoming calls. This is accomplished by the application of an earth potential to the final selector multiple from a contact of either the LC or LD relays, depending upon which party is the calling party.

(d) Ensures that the call will be registered against the calling party. This is done by the use of a contact of either LA or LB relays which loops the associated calling equipment of the calling party.

(e) In the event of an incoming call to either party the equipment shall operate in such a way as to apply ringing current to only the called party's line.

(ii) The main functions of the equipment installed at the subscriber's premises.

(a) Causes open line conditions to exist on the non-calling party's line during conversation, thus ensuring secrecy. The operation of either relay is accomplished upon the making, or receipt, of the call.

(b) Allows transmission efficiency to be maintained by the provision of condensers which offset the inductive effect of the relay sets.

(b) It is because of the low resistance of the A and B relays at the subscriber's premises that the earth connection must be of a low resistance. Should such resistance be comparable to, or greater than, the resistance of relay A or B then the operation of the relays would be greatly affected since the voltage drop across the relays would be reduced to a figure insufficient to fully flux the relay.

Q.3.—(a) If a fuse in the negative battery feed to any rank of switches in an unattended R.A.X. operates, explain briefly how this information is conveyed to the technician at the parent exchange.

(b) How does the technician confirm the general nature of such a fault without visiting the R.A.X.?

(c) If the ring supply at an R.A.X. fails, how is this detected from the parent exchange?

A.—(a) When a fuse operates in an unattended R.A.X. the earth from the fuse alarm circuit causes the automanual relay set to come into operation. Ringing current is connected to an outgoing junction line and the manual switchboard operator is signalled.

When the distant operator answers the ringing signal a series of operations at the R.A.X. cause the 570 ohm winding of relay AL to be connected to one or other of the tones, according to the fault condition prevailing.

The operator now hears a distinctive tone to indicate the nature of the alarm, in the case of an operated fuse this tone will be busy tone.

(b) The technician at the parent exchange can confirm the nature of the fault by dialling the fault test number.

The tones which may be heard after dialling the test number indicate to the testing officer the fault condition existing at the R.A.X.

In the case of an operated fuse, busy tone will be heard by the technician at the parent exchange.

(c) If the ring supply at an R.A.X. fails it may be detected by—

(i) Loss of all supervisory tones. This occurs when the ringing machine fails to start.

(ii) In the event of ringing current supply failing this could be checked by

(a) calling an exchange via the R.A.X. and checking the receipt of such a call via a direct magneto trunk.

(b) Calling through the R.A.X. and back to the parent exchange over another trunk.

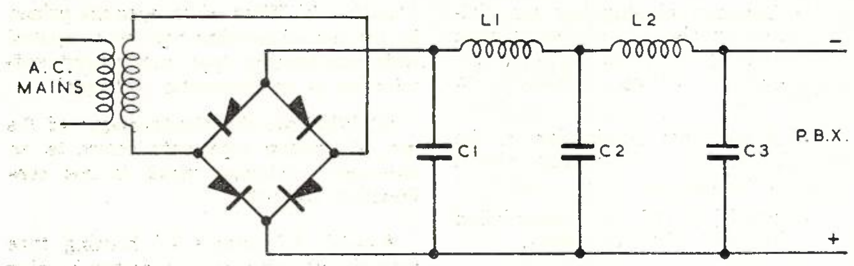
Q.4.—(a) Describe three methods of supplying D.C. power to a C.B. type P.B.X.

(b) In each of the three methods listed what arrangements are made to maintain service at the P.B.X. in the case of failure of the public power supply?

A.—(a) (i) Power leads. The most common form of supplying power to P.B.X. switchboards for extension to extension calls is by means of power leads. In this form of power supply to a P.B.X. board a group of conductors are joined in parallel and serve to join the negative bus-bar at the exchange to the negative bus-bar at the P.B.X. Since the positive bus-bars are earthed at the exchange and the P.B.X., it will be seen that power lead working is a single or earth return circuit.

The reason for placing several conductors in parallel is to reduce the resistance so that the potential drop over the power lead will be limited to a fixed maximum value which depends primarily on the exchange voltage, so as to maintain the P.B.X. voltage requirements under full load conditions.

(ii) Rectifier Unit. This unit consists of a full wave rectifier unit with smoothing equipment to enable the P.B.X. to be worked direct from the power unit. The diagram shows the principle of such a unit, the smoothing circuit consisting of two series inductances and three large



Q.4—Fig. 1.

capacity, shunt connected, electrolytic condensers.

(iii) Secondary Battery. In this case it may be economical to supply the P.B.X. with a secondary battery supply. This may be necessary in the event of the subscriber being some distance from the exchange so requiring a great number of conductors in parallel to form the power lead to fulfil the "maximum potential drop allowed" requirement. Under such circumstances it is possible to "trickle charge" such a battery from the exchange power supply over a metallic circuit.

(b) In the event of a public power supply failure the service at the P.B.X.'s in cases 1 and 3 would not be affected.

In case 2 such a failure would result in the loss of the extension to extension calling facility and call supervision. A limited service could be maintained by night switching the exchange lines to designated extensions where incoming calls could be answered, and from which calls could be originated.

Q.5.—(a) In an automatic main exchange it is necessary to provide additional third selectors and it is proposed at the same time, to rearrange the grading of the outlets from the second to third selectors. Give brief details of the method of carrying out the main jumpering or wiring changes necessary. State on what rack or apparatus the work would be performed and the necessary precautions which should be taken during this work to prevent interference with working circuits. State the type of exchange to which your answer refers.

(b) In a rank of switches fed by a graded group some switches get more use than others. Is this statement correct? State the reason for your answer.

A.—(a) Assuming all cables have been run, all outlets from second selectors are terminated on the T.D.F. and all switch positions in third selectors are cabled to the terminal block on the T.D.F.

Place switch (new third selector) in required position.

Run jumper from previously vacant position on O/G block to T.D.F. position.

Terminate jumper on terminal block position before attempting to alter the T.D.F. in any way.

Busy out the existing third selector which will be affected by the introduction of the new third selector by earthing the private wire on the T.D.F.

Terminate the jumper on the T.D.F. on the required outlet from the second selectors.

Remove commoning wire so that the new switch acquires its own trunk.

Remove earth clip from the private wire and so allow the existing and the new selector to be available for use.

Repeat this procedure for each new switch, carrying out such work at times of light traffic.

The above refers to the method used in 2000 type exchanges.

(b) The statement is correct, because in a graded group the trunks are tested in an invariable order—say 1 to 10.

In such a case the second outlet will be used only when the first is in use, the third only when both the first and second are in use and so on.

The first choice outlets will, therefore, carry the greatest amount of traffic, the later choices carrying only the traffic originated when the earlier choices are in use. Thus at times of light traffic the later choice trunks may carry little or no traffic. During the busy hour, however, the traffic will be more evenly distributed to the switches because of the grading pattern.

Q.6.—(a) In a 2000 type group selector, what functions are performed by the following relays?

(i) C.

(ii) HA or HB.

(b) What would be likely to cause a 2000 type group selector:

(i) to pass idle trunks;

(ii) to stop on any busy trunk?

A.—(a) The functions of the C relay are:—

(i) To operate under the control of the "B" relay and prepare the impulsing circuit to the vertical magnet.

(ii) To release after the vertical impulses and complete the rotary magnet circuit.

(iii) To complete the operation of the testing relays HA and HB.

(iv) When a free trunk is found to reoperate and switch the subscriber through to the switch ahead.

The functions of the HA or HB relays are to test the upper and lower ten bank contacts of the private bank. Both relays will remain operated when testing busy contacts but either or both will restore when a free trunk is found, the switching relay C will reoperate and switch the call through. In the event of both trunks testing free provision is made for the reoperation of relay HA. Whilst the call is in progress HA or HB will be held operated by an earth returned on the release trunk from the switch ahead.

(b) (i) Increased release lag of the HA or HB relays, possibly due to a decrease in the residual air gap, would allow a further rotary step to occur even though the wipers may have come to rest on an idle trunk.

(ii) (a) Faulty alignment of wipers on the bank contacts.

(b) Faulty wiper adjustments.

(c) Faulty adjustment of rotary interruptor contacts.

(d) Backlash in the rotary magnet adjustment causing wipers to "overshoot".

(e) High resistance contacts between wipers and banks.

(f) Intermittent open of wiper cord.

Q.7.—(a) Briefly list the main facilities provided by a C or CA type P.A.B.X.

(b) Explain briefly the circuit operations involved, at the extension and in the unit, when an extension connected to this type of P.A.B.X. originates a call back to another extension while holding an exchange call. A circuit diagram is not required.

A.—(a) Main facilities provided by C or CA type P.A.B.X.'s are:—

(i) Extension to extension calls direct.

(ii) Outgoing calls may be made to the exchange direct from extensions after dialling "Y".

(iii) Extension may be "Barred Exchange Access".

(iv) Calls to the switchboard by extensions by dialling 9.

(v) Exchange calls may be reverted to extension by the operator.

(vi) An exchange call may be offered to a busy extension by the telephonist.

(vii) An extension may hold an exchange call and call another extension.

(viii) Night switching of exchange lines to selected extensions.

(ix) Incoming exchange line calls on switchboard may be routed to extensions at the discretion of the operator.

(x) "Camp On"—an exchange call for a busy extension "camps on" and when extension is free cuts through.

(xi) Through clearing and automatic release of exchange calls through switchboard.

(xii) Automatic transfer, both way exchange calls may be automatically transferred by extensions without recalling the switchboard.

(b) The extension, connected to the exchange call depresses the non-locking key once, the contacts of this key earth one side of the line causing the differentially wound relay D to operate.

The operation of D causes relay RC to operate and the contacts of this relay connect a 600 ohm resistance across the exchange line, thereby holding the exchange call.

The extension is directed into the Call Back Circuit and to the spare extension line circuit so that the calling extension obtains local dial tone from a local or link selector and dials the required extension.

When the extension wishes to return to the exchange line, the non-locking key on the telephone is again depressed; RC releases and in doing so reconnects the extension to the exchange line and disconnects the extension from the link circuit.

Q.8.—(a) On a sleeve control CB multiple country switchboard, the following three types of position are provided:—

(i) "A" Position.

(ii) Terminating trunk position.

(iii) Through trunk position.

What relay sets are installed in each of these positions?

(b) On a terminating trunk position it is necessary to connect local subscribers to trunk lines. Give a brief description of the facilities provided in the speaking part of the cord circuit to allow for this condition.

A.—(a) The relay sets associated with each position are as follows:—

(i) A position.
- (a) Cord circuit relay set.
- (b) Position circuit relay sets.

(ii) Terminating Trunk Position.
- (a) Cord circuits relay sets.
- (b) Position circuit relay set.
- (c) Telephonist's circuit relay set.
- (d) Time check relay sets.

(iii) Through Position.
- (a) Cord circuits relay sets.
- (b) Network cords circuits relay sets.
- (c) Position circuit relay set.
- (d) Telephonist's circuit relay set.
- (e) Time check relay sets.

(b) (i) Facility to divide the cord circuit to enable the telephonist to speak on either side of the cord circuit to the exclusion of the others.

(ii) Cord circuit speaking keys arranged to prevent the operation of two speaking keys on the same position being effective.

(iii) Position ringing key for trunk cords and cord circuit ringing keys for subscriber's cords.

(iv) Common dialling key for dialling on either cord, giving loop dialling on subs. and the required dialling condition on trunks.

(v) A 600 ohm termination on the trunk line when the cord circuit is split.

(vi) Provision of a transmission bridge for battery supply.

Q.9.—(a) In a voice frequency system of the 2 VF type, two tones are used, what is the frequency of these tones and for what purpose are they used in the system?

(b) By means of a block schematic diagram show how a 2 VF both way working trunk line is terminated at a location which includes—

(i) An automatic exchange or network.

(ii) Trunk manual position.

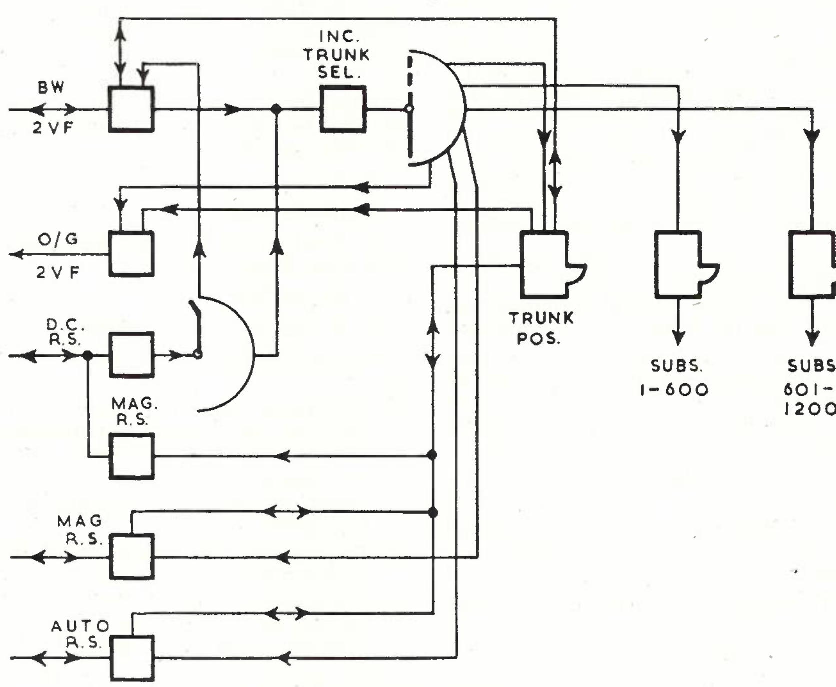
(iii) Other trunk lines available via automatic trunk switching equipment.

A.—(a) The frequency of the two tones used in a voice frequency system of the 2 VF type are 600 cycles per second; known as the Y pulse and 750 cycles per second; known as the X pulse.

The function of the X pulse of 750 cycles per second are concerned with pick up calling, dialling, and recall signals.

The function of the Y pulse of 600 cycles per second is used for supervisory purposes in both directions during the call.

(b)



Q.9—Fig. 1.

Q.10.—(a) What advantages are gained by the use of homing type as compared with non-homing type subscribers' uniselectors in an automatic exchange?

(b) What are the disadvantages of the use of homing type uniselectors in an automatic exchange which is not continuously staffed?

A.—(a) Advantages of homing type subscribers' uniselectors over non-homing uniselectors are:—

(i) The outlets may be graded, this results in a saving of up to 20 per cent. in the total number of first selectors required.

(ii) Will step over open circuit trunks.

(iii) The mechanical latch and face plate on the line and cut off relays are eliminated.

(iv) Less liable to contact faults due to the cleaning action of the wipers on the bank contacts.

(v) Eliminates chain contact method of all trunks busy.

(b) Disadvantages of the use of homing type uniselectors in non-attended exchanges are:—

(i) Should any first choice switch become unserviceable it would mean that the homing type uniselectors would continue to seize the associated trunks to such a switch and in doing so prevent subscribers from making a call.

(ii) Possibility of a mechanical fault preventing the self-interrupted drive to the home position from functioning, in such a case there is a grave fire risk.

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