THE
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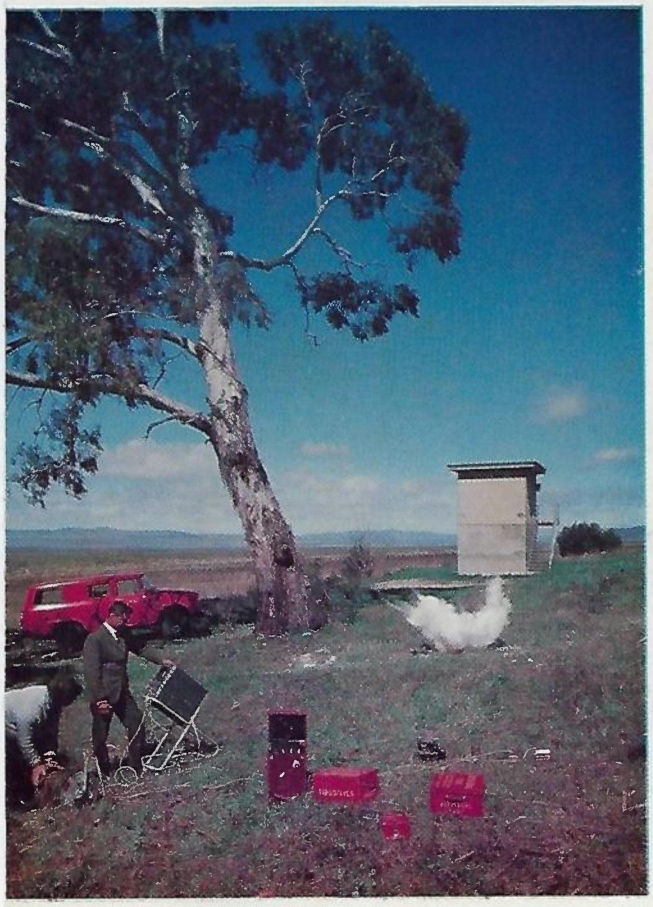

IN THIS ISSUE

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OCTOBER, 1969

THE
TELECOMMUNICATION JOURNAL
OF AUSTRALIA

VOL. 19 No. 3
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COVER
Blasting near
Coaxial Cables
(Picture shows effect
of exploding one
detonator in chalk.)

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NUMERICAL DESIGN OF RELAY CIRCUITS

*J. E. SANDER, B.Eng., Tek.Lic.**

INTRODUCTION

The first numerical methods for the design of relay circuits were proposed by Roginskii (Refs. 1, 2) and by Scheinman (Refs. 3, 4), about 1959. Since that time the methods have been extended and automatic machines and computers, using these methods, have been developed to design circuits automatically (Refs. 2, 6).

In normal, day-to-day, relay circuit design work most of the problems which arise are small, and quite amenable to solution by the informal 'intuitive' methods commonly used by most circuit designers. Whenever large or complex design problems arise, however, there is an understandable tendency for most designers to continue to try to reach a solution with their favourite intuitive method, rather than to try to apply some of the more effective formal methods now available. (Refs. 5 and 6.) The particular method of circuit synthesis described in this paper is simple to use and it gives good, straightforward solutions to most circuit problems almost irrespective of the number of relays involved. The more highly developed method of circuit synthesis described in Ref. 6 is capable of giving a better solution (i.e., a solution with a smaller number of relay springs), but it requires rather more skill to apply.

The basic method of circuit design described below is a simplified version of the method described in Ref. 6 and it retains the main virtues of that method, which are:—

(i) Only a moderate increase in complexity occurs when a large number of relays is required, compared with the rapid increases in complexity which occur when any of the methods discussed in Ref. 5 are applied to problems involving, say, 6 or more relays.

(ii) The actual circuit solutions obtained by numerical methods evolve directly as the synthesis proceeds. They do not need to be 'reconstructed' at the end from some form of algebraic representation as with most other methods.

(iii) The amount of work required to produce a circuit solution is proportional only to the number of 'states' which the circuit relays assume in normal operations, and not proportional to the total possible number of relay states, as is often the case.

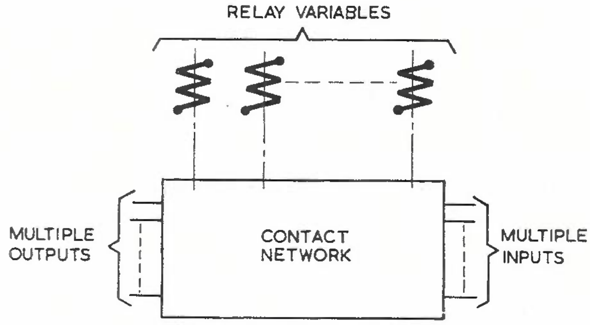


Fig. 1.

SPECIFYING THE CIRCUIT PROBLEM.

The first barrier in any formal method of design is the work required to re-specify the circuit problem in a form suitable for mathematical handling.

In the method described here the circuit requirements are specified as a series of decimal numbers derived from a normal relay state diagram (or relay sequence diagram). Examples are given later.

The numerical method of contact network design can be applied to circuits of the kind illustrated diagrammatically in Fig. 1. Initially, however, in this paper the circuit examples will only be of the 'single input terminal' kind illustrated in Fig. 2. (This is not a very great restriction in practice, as almost any relay circuit whatsoever can be broken up into functional groups of contact trees of the single input type. As an illustration, the single input contact tree shown in Fig. 2 could have + (or earth) connected to its input, and various output terminals, signalling wires, relay coils, lamps or other devices, connected to its output terminals. (The terms 'input' and 'output' as used here are not intended to be taken literally; they are used only as convenient descriptive labels, and do not necessarily represent particular directions of current or energy flow).). Ref. 6 contains a full description of the numerical synthesis method applied also to circuits of the Fig. 1 type.

SAMPLE PROBLEM No. 1.

It is desired to design a relay circuit which will light an alarm lamp when relay A and relay B are operated; also the lamp must light when relay A and relay C are operated. The lamp must not light, however, when all three relays are operated, nor when any single relay is operated.

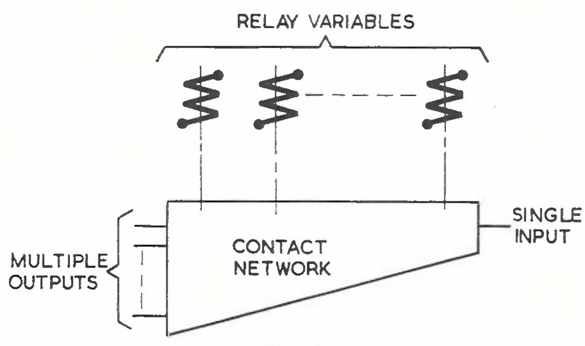


Fig. 2.

* Mr. Sander is Engineer Class 4, Telephone Exchange Equipment Section, Headquarters.

Relay States. A Wt.=1	B Wt.=2	C Wt.=4	Output Lamp Condition.	State Numbers.
0	0	1	Off	4
0	1	0	Off	2
1	0	0	Off	1
1	0	1	On	5
1	1	0	On	3
1	1	1	Off	7

Note: 0 means relay released; 1 means relay operated.

Fig. 3.

The relay conditions are first set out in a table as in Fig. 3. It is only necessary to set out the relay condition which actually occur during operations of the circuit. All other conditions may be ignored.

Each of the (three) relays is then allocated a 'weight number' starting with 1, and rising as ascending powers of 2, i.e., 1, 2, 4, 8, 16, etc. It does not matter which relay is allocated which weight as the final answer will still be correct. Different ways of allocating the weights amongst the relays will result in different final circuits, but each circuit will still give the desired result.

The weights of each *operated* relay are now added together and placed in a column of 'State Numbers.' (See Fig. 3.)

The two 'State Numbers' which correspond to the circuit closed (or lamp ON condition) are called essential numbers, and together they form the Essential set, or E-set. That is:

E = 3, 5.

The four numbers which correspond to the circuit open (or lamp OFF condition) are called barred numbers, and together they form the Barred set, or B-set. That is:

B = 4, 2, 1, 7.

Now, following the procedure illustrated in Fig. 4 (a), the numbers in each set are 'processed' according to the following rules:

Rule (1): Take each individual state number from the incoming E-set and compare it with the weight of the relay. (N.B.: Start with the relay of highest weight.):

(a) If it is *less than* the weight of the relay write it on top of the *break*-wire.

(b) If it is *equal to or greater* than the weight of the relay, subtract the weight of the relay from it, and write the result on top of the *make*-wire.

Rule (2): Take the state numbers from the incoming B-set and compare each one with the weight of the relay as above.

Then apply (a) and (b) from Rule (1) as before, except that in each case write the result *under* the break-make wires.

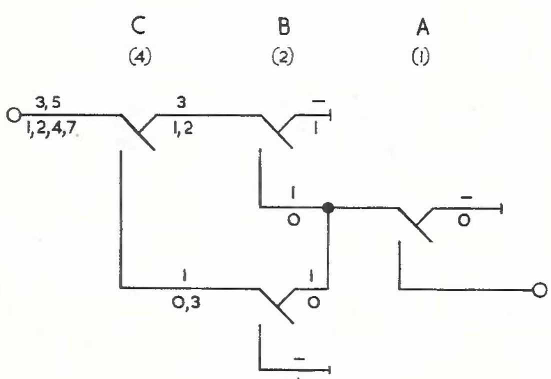


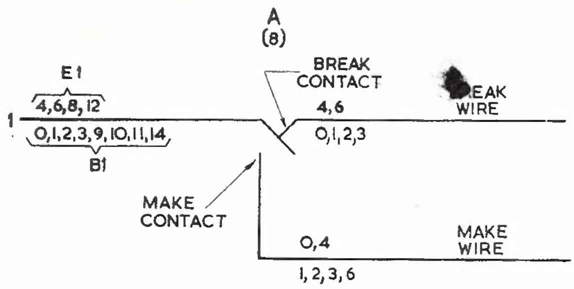
Fig. 4 (a).

Rule (3): Apply Rules (1) and (2) to all output wires.

Rule (4): Check if any of the make or break wires can be joined with any of the other make or break wires *without* causing the same state number to appear both above and below the line.

Rule (5): Repeat all the above for each of the remaining relays in turn, working in each case with the relay of next highest weight.

All of the five above Rules are applied to the E-sets and B-sets for



NOTE. E-SETS ARE WRITTEN ABOVE EACH WIRE.
B-SETS " " BELOW " "

Fig. 4 (b).

the single output in Fig. 4 (a). (Output No. 1, of sample problem 2, is also treated in a similar manner in Fig. 4 (b)....)

Redrawing Fig. 4 (a) with battery, and relay coils, we get the circuit in Fig. 5. Note that the make and the break springsets on relay B have been re-arranged, for economy, to save one relay spring.

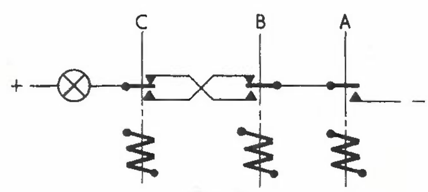


Fig. 5.

SAMPLE PROBLEM No. 2.

Imagine that as part of a relay set specification there is the problem of designing a circuit to absorb the first of two pulses received, and then to generate an output pulse for the third, and every third, succeeding input pulse. The problem may be solved by first constructing a logically consistent relay sequence diagram and adding the necessary secondary relays as shown in Fig. 6. (Any trial-and-error, intuitive, or formal method, as the designer wishes, may be employed here to determine the necessary secondary relays. For example see Ref. 7.)

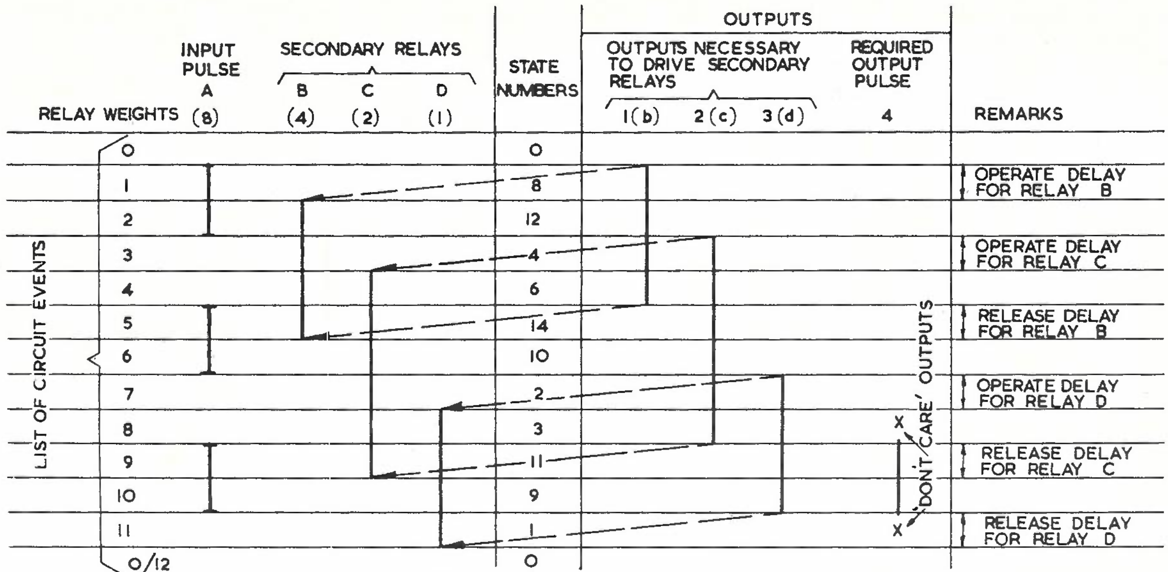


Fig. 6.

The bracketed figures appearing under the names of the relays A, B, C, D in Fig. 6 are the relay 'weights,' and the first step is to utilise these relay weights to produce the so-called 'transmission sets.'

As explained before, the weights may be allocated to the relays in any order, provided that weights beginning at the value 1, and ascending in powers of 2, are used. In this example weights have been allocated as follows:—

relay D has weight 1
,, C ,, ,, 2
,, B ,, ,, 4
,, A ,, ,, 8

If the weights are allocated in any other order the final circuit will still be correct but, as before, it may be different to the result obtained with the weights allocated as shown in this example. There are obviously many different ways the weights may be allocated to the relays (N! in fact, if N = number of relays) and, in general, there are N! different possible solutions to any problem using the numerical method described here.

'Circuit State Numbers' are then added to the sequence diagram as before, in a separate column, by adding together the weights of the *operated* relays in each circuit condition.

Using these 'state numbers' it is now possible to derive the 'essential sets' and 'barred sets' for each output for each state of the circuit. These Essential sets (or E-sets), and Barred sets (B-sets), as before, consist of the set of state numbers which apply to the conditions required at each output when a circuit path is 'essential' (or a circuit path is 'barred') in each case.

Output 1, which operates relay B, obviously should not provide any circuit to relay B when the circuit is in state '0,' therefore '0' is one number from the set of 'barred' states for output 1.

The next state '8' for output 1, is obviously one in which it is essential to provide a circuit to relay B. Therefore state 8 is a number from the set of 'essential' states for output 1.

Similarly the remaining state numbers for output 1, and for each of the other outputs (including the desired output pulse on output wire 4) can be assembled as shown in the transmission sets below:—

E_1 = 8, 12, 4, 6
E_2 = 4, 6, 14, 10, 2, 3
E_3 = 2, 3, 11, 9.
E_4 = 11, 9.
B_1 = 0, 14, 10, 2, 3, 11, 9, 1.
B_2 = 0, 8, 12, 11, 9, 1.
B_3 = 0, 8, 12, 4, 6, 14, 10, 1.
B_4 = 0, 8, 12, 4, 6, 14, 10, 2, 0.

E_1 means the essential states for output 1.

B_3 means the barred states for output 3, etc.

(The 'don't care' states corresponding to the X's shown in Fig. 6 on output number 4 are merely ignored.)

The E-sets and B-sets are now written at the left-hand side of a blank sheet (with the numbers of each set re-arranged in ascending order for convenience, see Fig. 7), and each number of each set is then 'processed' as shown in the short example in Fig. 4 (b), (which shows only output number 1).

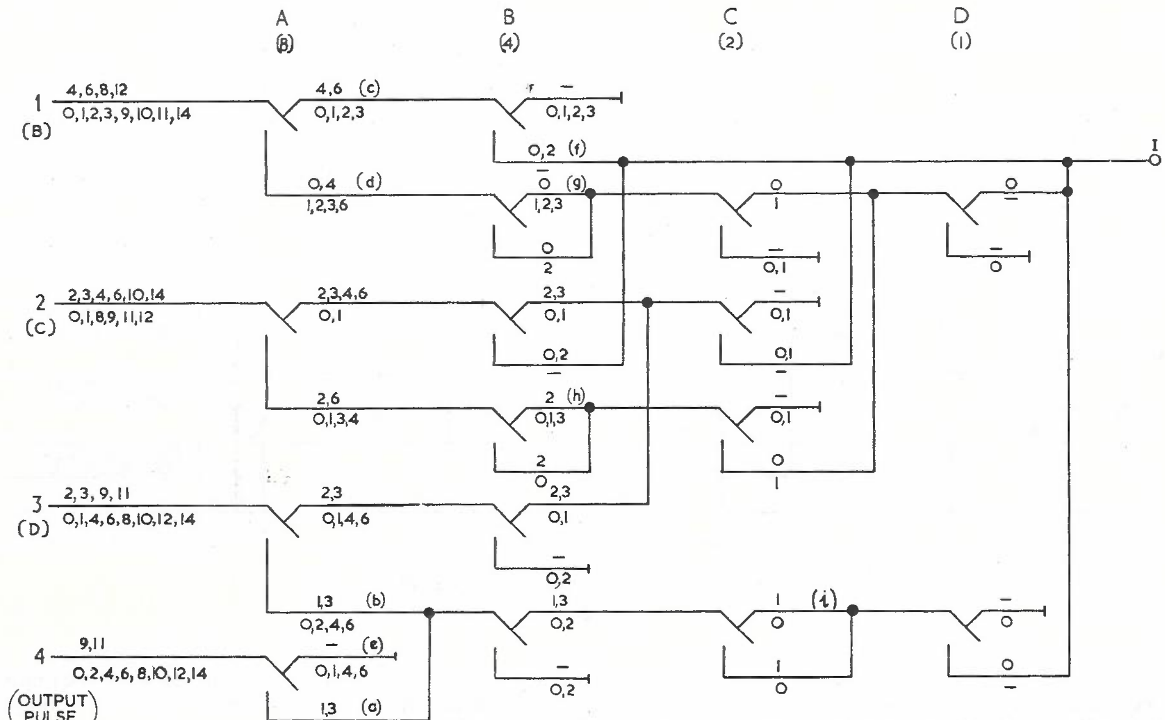
In Fig. 4 (b) and subsequently in Fig. 7, changeover contacts have been drawn for each of the four outputs on relay A (the relay with the highest weight), and the E_1 and B_1 sets 'processed' through the contacts using the five Rules given above.

In the circuit diagram of Fig. 7, it is clear that wires (a) and (b) can be joined together ('merged' is the correct technical term) without contravening Rule (4). Wires (c) and (d) on the other hand cannot be merged, because if they were merged, a new resultant E-set = 0, 4, 6, and a new resultant B-set = 0, 1, 2, 3, 6, would be formed. Terms '0' and '6' appear both in the E-set and in the B-set, and this is obviously impossible. It means that such a merged wire would be simultaneously required to be connected to the input wire in state '0,' and at the same time be barred from the input in state '0.' Similarly for state '6.' Such mergers are clearly not possible.

Wires such as (e), which do not have any terms in their E-set are just abandoned and the associated contact not provided.

The contacts for the relay with the next highest weight, relay B with weight 4, are then derived as before.

This time more mergers become possible, and in addition a new situation occurs at (f). At this wire a B-set is derived which has no terms in it at all. This merely means that the particular wire does not need to



NOTE. THE SYMBOLS USED FOR RELAY MAKE & BREAK CONTACTS IN THIS DIAGRAM ARE USED BECAUSE THEY ARE PARTICULARLY WELL SUITED TO THIS TYPE OF CIRCUIT DESIGN.

Fig. 7.

be barred to any further states and it is quite correct to extend it right through to the input terminal I.

After making all possible mergers, and eliminating all wires which have empty E-sets, the remaining wires are then processed in order through the relays of decreasing weight as shown. It will always be found that after the last relay of weight '1' all the wires will merge on to the input terminal I.

The mergers which are shown at (g), (h) and (i) are quite correct and the obvious result of these is that the preceding (short-circuited) change over contacts on relays B and C are not required at all. When re-drawing the contact network on to the final circuit diagram, Fig. 8, these contacts are of course replaced by straight-through wires.

In order to now make the complete circuit output 1 is connected to the coil of relay B, output 2 to the coil of relay C and so on as shown below. Also wherever possible individual make and break contact units are combined into changeover units. See Fig. 8.

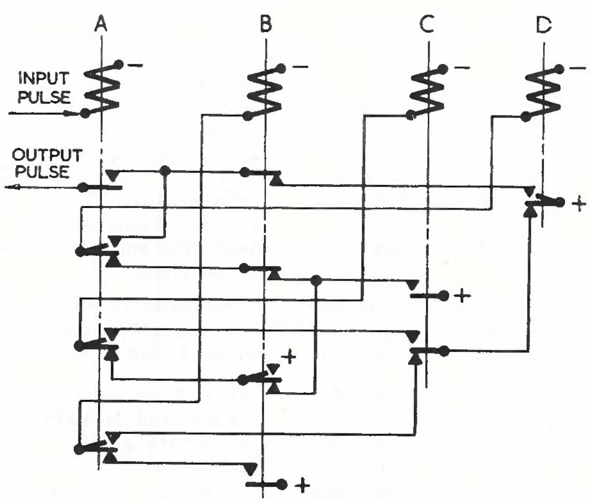


Fig. 8.

One final requirement is that the circuit be visually inspected and whenever necessary changeover contact units be replaced with make-before break units to ensure continuity of the holding paths to relays B, C and D.

COMPUTER DESIGNED CIRCUITS.

By means of applying an extension of the above method of numerical synthesis (employed so-called 'direct-leads') (See Ref. 6), it is possible in most cases to reduce the number of relay springs required to make up any given circuit. Also by re-arranging the allocation of relay weights and working through the problem again, it is possible to obtain a different circuit solution which still fulfils the original requirements. This different solution may or may not contain a greater or a lesser number of relay springs than the solution obtained above. It is in these areas of applying direct leads, and of 'searching' over different allocations (permutations) of relay weights, that computer methods are most useful and an example of a large circuit designed completely on a digital computer is shown in Fig. 9.

In this diagram break contacts are shown as ---/---, and make contacts are shown ---X---, and they are arranged in each case in a direct line underneath the appropriate relay name printed at the top of the diagram.

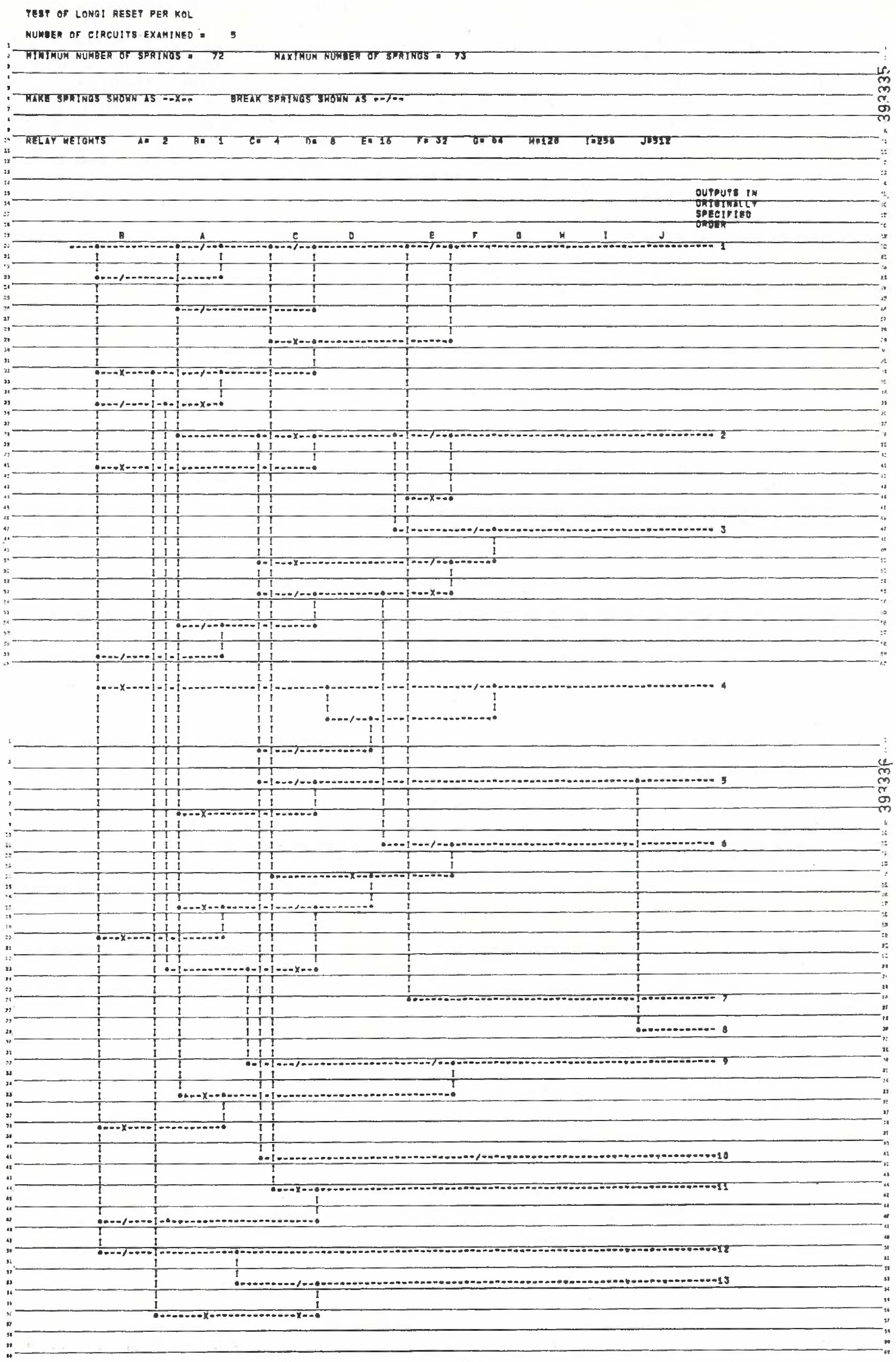

TEST OF LONGI RESET PER KOL
NUMBER OF CIRCUITS EXAMINED = 5
MINIMUM NUMBER OF SPRINGS = 72
MAXIMUM NUMBER OF SPRINGS = 73
MAKE SPRINGS SHOWN AS --X--
BREAK SPRINGS SHOWN AS --/--
RELAY WEIGHTS A= 2 B= 1 C= 4 D= 8 E= 16 F= 32 G= 64 H=128 I=256 J=512
OUTPUTS IN ORIGINALLY SPECIFIED ORDER
B A C D E F G H I J

Fig. 9.

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KEY LOGIC RELAY CIRCUIT

*F. M. SCOTT, A.M.I.R.E.E. (Aust.)**

INTRODUCTION

The recently introduced A.P.O. Four-Wire Cord Type Manual Assistance Centre, System AFM402 (Ref. 1), uses non-locking push-button keys for all functions on the Type "E" Trunk Assistance Position, the Special Services position and the Monitor's and Supervisor's turrets. Many of these keys control locking circuit functions, such as the operation of a speak key. The non-locking action of the key must therefore be converted to a locking function by the use of relays. These groups of relays are known as key logic relays and are contained in key logic relay sets designated by the prefix code OKR. This article explains the functions provided by the logic relays and outlines the circuit operation of a typical control circuit.

LEVER AND PUSH BUTTON TYPE KEYS

Prior to 1969, A.P.O. trunk assistance switchboard positions employed mainly lever type keys for all functions except digit keying and order wire connection. Locking type lever keys were used for speak and monitor key functions, while spring loaded non-locking lever keys performed functions such as ringing, metering, dividing, etc., which are of a brief duration. An operated lever key in a line of keys is easily recognisable due to the physical displacement of the lever, and therefore no other indication of its operation is required.

The facility schedule for the new A.P.O. Four-Wire Trunk Assistance and Special Services positions which are part of Systems AFG201 and AFM402 calls for the use of push-button type keys for all keyshelf functions which are key controlled. The Erga key is used for general key functions, while the Licon microswitch key is used for digit sending. Photographs of these keys appeared in Volume 19, No. 1, of the Journal (Figs. 9 and 10 on page 47).

The Erga key has a fixed complement of two changeover contact units and two independent lamp sockets. Two actions are available: non-locking and alternate. The non-locking key has the normal spring-loaded restore action and is suitable for heavy duty applications. A modified version of this key providing an alternate action is available, but the life expectancy is somewhat shorter than that of the non-locking type. In the alternate action key the first pressing of the key knob mechanically latches the key so that the springsets remain actuated when the finger is removed from the key knob. When the key is pressed a second time, the latch is released and the springsets restore to normal following removal of the finger from the key knob.

The Erga push-button key has the following advantages on a switchboard keyshelf:—

(i) Improved operating efficiency. Push-buttons can be manipulated quicker than lever keys and with less physical effort.
(ii) Compactness. The Erga key contains two integral lamps which can be operated independently or in parallel.
(iii) Improved keyshelf appearance. This results from the almost flush mounting of the keyknobs and the absence of keys and lamps of differing physical appearance.

The main disadvantages are the lack of memory and the limitation of only two contact units. To compensate for these deficiencies, relays must be added to the circuit. These provide the memory functions, and, due to their greater contact loading potential, provide the means of introducing multiple contact actions for control and chain circuits. A secondary advantage from the use of memory relays is the availability of a mutual release facility whereby the operation of one key can be used to release a function previously established by another key. The first key operated does not have to be manually restored.

In System AFM402 the key logic relays are grouped in OKR relay sets, each of which controls a particular set of functions. Fig. 1 shows typical circuit elements for a key logic circuit controlling a set of speak functions. The following conditions must be met:

(i) No relays should be operated when the circuit is idle.
(ii) It should not be possible to connect to more than one circuit by operating several keys simultaneously.
(iii) A function should be set by momentarily pressing the desired key.
(iv) The function should be released by pressing the same key a second time, or by pressing another key arranged in a mutual release chain circuit.
(v) The operation of the circuit should not depend upon sequencing of the key contact units.
(vi) When transferring from one circuit to another in a key group, e.g., from speaking on one cord circuit to speaking on another cord circuit, the key logic circuit should ensure that the first device is fully disconnected before the second is seized.
(vii) Single finger operation of the key group should be possible.
(viii) Resistance in the wiring between the keys and the relays should not be a critical factor in the circuit design.

CIRCUIT OPERATION

Referring to Fig. 1, the key logic relay set comprises one relay for each circuit controlled (S1 to S6), plus two common relays SX and SY. Thus for a key logic circuit providing the locking function under the control of one non-locking key, three relays are required (S1, SX and SY), but for additional keys in the group only one relay per key is added.

When Speak Key 1 is pressed earth potential at the key is connected to wire 1 to operate the S1 relay to battery via its 2000-ohm winding and the break contact units of SX and SY. S1/12-13 and 33-34 provide holding for S1 independent of the key and the SX and SY break contact units. When the Speak Key is allowed to restore under spring tension, earth at the key operates the SX relay via S1/35-36. SX then holds via SX/25-26 independent of the key earth. SX/27-28 in conjunction with S1/15/16 provides an operate path for the relay in the controlled circuit, e.g., SNOR. S1/31-32 connects the key operated lamp located in Speak Key 1, which lights to indicate that the key function is connected.

The chain circuit through S1-6/11-12-13 ensures that holding is available to only one of the S relays at any time. The chain circuit through S1-6/14-15-16 allows only one external device to be actuated at a time. SX/21-22 opens the initial operate circuit to all S relays.

Release can be arranged in two ways. Firstly, by re-pressing the same key. The earth at Speak Key 1, when operated, is again connected to wire 1, where it provides an alternate hold path for S1 and also operates relay SY via SX/23-24. SY breaks the circuit to the controlled SNOR at SY/13-14, opens the local hold circuit for S1 at SY/15-16 and further opens the

* Mr. Scott is Engineer Class 3, Internal Equipment, Queensland. See Vol. 19. No. 1. P. 77.

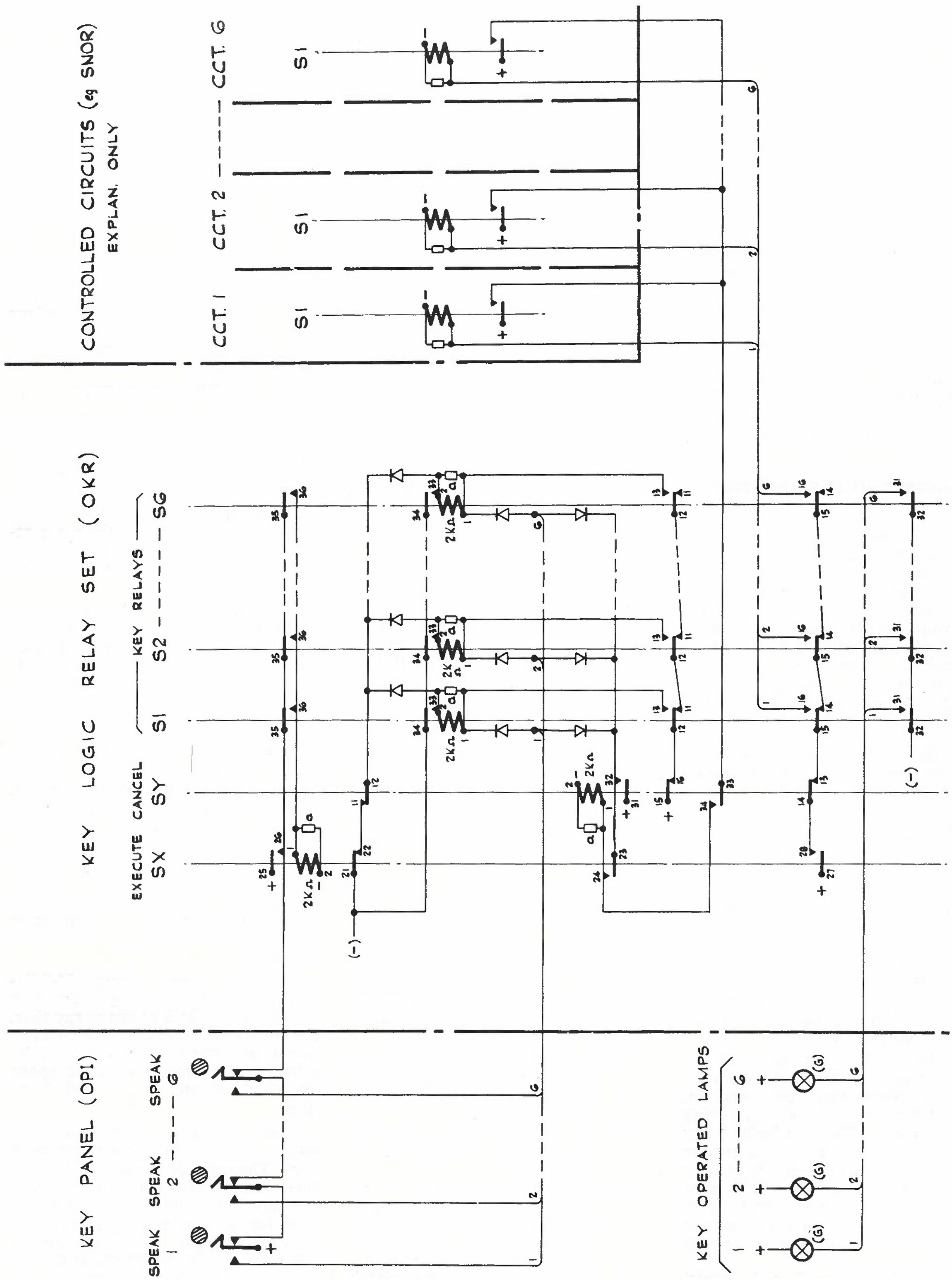

Fig. 1. — Typical Key Logic Circuit Elements for Use with Non-Locking Push Button Keys.

initial operate path of the S relays at SY/11-12. In addition to the original operate path, SY receives holding from SX/23-24 and SY/31-32, and also from the controlled circuits via SY/33-34.

When Speak Key 1 is restored to normal S1 releases. SX is released by S1/35-36 and SX/23-24 breaks the local hold circuit of SY, leaving it dependent upon the guarding earth returned from the SNORs. When SNOR 1 is disconnected, SY will release and SY/11-12 prepare the S1-6 relays for further operation.

In the second method of release a different speak key in the same mutual release chain is operated, say number 2. The operation of Speak Key 2 with S1 already operated will not operate S2 as the initial operate path is broken at SX/21-22. Speak Key 2 does, however, operate SY, which releases SNOR number 1 and relay S1 at SY/15-16. S1/35-36 releases SX. When SNOR number 1 restores, SY will release. With SX and SY both normal and Speak Key 2 operated, a path is provided to operate relay S2, which holds via SY/15-16 and S2/12-13. When Speak Key 2 is restored, SX operates and at SX/27-28 a circuit is provided to operate SNOR number 2 via S2/15-16. Release of the Speak Key 2 function can be accomplished either by re-pressing Speak Key 2 or by pressing another speak key in the same mutual release chain.

The mutual release facility may be extended to provide mutual release between speak and monitor groups. In this case Speak 1 releases Monitor 1 and vice versa. Speak 2 releases Monitor 2 and vice versa, and so on. The hold path of S1 would include a break contact unit of M1 while the hold circuit of M1 would contain a break contact unit of S1 and so on. A similar arrangement can apply between speak and hold keys associated with automatic exchange lines and switchboard junctions wired to turret positions.

BINARY NOTATION

The above circuit operation may be expressed in shorthand form by the use of binary notation as used in Boolean Algebra. A relay has two steady states—operated and unoperated.

These are represented by the use of superscripts 1 and 0. Superscript 1 indicates operation, while 0 indicates the normal condition. Thus relay S1 operated would be shown as S1^1 and when unoperated as S1^0.

The circuit operation for the pressing and releasing of Speak Key 1 to connect to SNOR-1, then the repressing and releasing of Speak Key 1 to disconnect SNOR-1 can be represented as follows:—

$$1.\ \begin{cases} \text{Key } 1^1 \rightarrow \text{S1}^1 \\ \text{Key } 1^0 \rightarrow \text{SX}^1 \rightarrow \text{SNOR-1}^1 \end{cases}$$

$$2.\ \begin{cases} \text{Key} 1^1 \rightarrow \text{SY}^1 \rightarrow \text{SNOR-1}^0 \\ \text{Key } 1^0 \rightarrow \text{S1}^0 \rightarrow \text{SX}^0 \rightarrow \text{SY}^0 \end{cases}$$

The second form of release, as previously described, may be represented as follows:—

$$1.\ \begin{cases} \text{Key } 1^1 \rightarrow \text{S1}^1 \\ \text{Key } 1^0 \rightarrow \text{SX}^1 \rightarrow \text{SNOR-1}^1 \end{cases}$$

$$2.\ \left\{\begin{array}{l} \left.\begin{array}{l} \text{Key } 2^1 \rightarrow \text{SY}^1 \rightarrow \text{SNOR-1}^0 \longrightarrow \\ \qquad\qquad\quad \searrow \text{S1}^0 \rightarrow \text{SX}^0 \longrightarrow + \end{array}\right\} \longrightarrow \text{SY}^0 \rightarrow \text{S2}^1 \\ \text{Key } 2^0 \rightarrow \text{SX}^1 \rightarrow \text{SNOR } 2^1 \end{array}\right.$$

CONCLUSION

The facilities developed for the key logic circuit are not related exclusively to the Erga key, but would find general application with any spring loaded non-locking push button key used to control locking functions. Many other arrangements of the key logic circuitry could be devised, some perhaps with less relays. A circuit with minimum relays is always the aim of a circuit designer, but this is not the main criterion of good circuit design. The circuit described is simple and functional, and does not rely on sequenced contacts, relay timing, marginal current, critical adjustment, balanced windings, or any special components for its operation.

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OPTIMUM DESIGN OF TAPERED BUSBAR SYSTEMS

*Y. F. TONG, B.E. (Hons.)**

INTRODUCTION

There has been an extensive use of busbars in d.c. power distribution systems in Australian Post Office telephone installations. In the early days, copper busbars predominated the scene. However, in recent years, aluminium busbars are widely used instead of the copper type because of three main factors:—

(a) Aluminium is cheaper than copper, to the extent of about 2.5 to 1 price ratio in favour of aluminium (this figure has taken into account the difference in conductivity between copper and aluminium).
(b) Aluminium is lighter.
(c) There have been great improvements in aluminium busbar welding and joining techniques, thereby providing satisfactory electrical contact.

Also, there has been, in recent years, a tendency to introduce aluminium cables into power distribution systems; but experience has indicated that it is still more economical to use busbars in the main and submain distribution runs. This is particularly true in very large exchanges where the designer needs to overcome the problems of supporting a big group of power cables and also arranging them in an optimum manner to minimise introduction of electrical noise into the exchange circuits, especially when they are used in the closed coupling mode (see Ref. 1).

It is common practice to use cables or untapered busbars in small exchanges but in larger installations, busbars are invariably used. A general design calculation guide for both untapered and tapered busbar runs was considered by M. W. Gunn (Ref. 2). In the discussion on tapered busbar design, Gunn considered only a small number of cross-sectional area changes at arbitrarily selected positions along the busbar run. Admittedly, the few cross-sectional area changes considered were for practical reasons. However, there remains the question of whether the design based on the arbitrarily selected positions represents an optimum design. If not, then how can these changes in cross-sectional area be selected in an optimum manner in order to obtain an acceptable design?

The purpose of this paper is to present an analytical method of optimum design of tapered busbar distribution systems using the minimum cost criterion.

DESIGN BASIS

Since the A.P.O's adoption of the L. M. Ericsson's Crossbar System in the Australian Telephone Network, all new telephone exchanges have been of the crossbar type and as such the basis of busbar design must be revised to be compatible with the following requirements of crossbar equipment:

(a) Allowance of a maximum of 1.5 volts voltage drop from the battery terminals to the most remote equipment rack of the ultimate installation when the maximum load current is flowing.
(b) Allowance of a maximum current density of 500 amp/sq. in. for discharge circuits and 1,000 amp/sq. in. for charge circuits.

These allowable figures are stipulated to keep the generation of thermal noise in the circuits to a low and acceptable figure (see Ref. 1).

A breakup of the allowable voltage drop given in basis (a) is shown in Table 1.

TABLE 1: MAXIMUM ALLOWABLE VOLTAGE DROP

Busbar Run	Allowable Voltage Drop
Battery terminal to main d.c. power distribution panel	0.5V.
Main d.c. power distribution panel to suite power distribution box	0.75V.
Suite power distribution box to rack fuse	0.25V.

DESIGN CONSIDERATIONS

Consider now the following general power distribution system as shown in Fig. 1.

The section PQ represents the charging circuit and its design is a relatively straightforward application of the design bases given above. In most cases, this section is short and the controlling factor in design is the current density basis.

Beyond Q are the discharge circuits, e.g. the main busbar run QXYZ, and the submain runs X, X_1, X_2 .... X_{L-1}, X_L; Y Y_1 .... Y_{M-1} Y_M; and Z Z_1 .... Z_{N-1} Z_N; which feed the various suites. In a very large exchange installation, discharge circuit QXYZZ_1Z_2 .... Z_N could be of the order of several hundred feet which makes design basis (a) the controlling factor. Nevertheless, it would still be necessary to check that in no part of the discharge circuit, with the ultimate current load flowing, should the current density exceed 500 amp/sq. in.

In a busbar run, the current flowing in the busbar changes at each take-off, and the current flowing in the busbar section between two take-offs remains constant and so will the cross-sectional area required. Taking this fact into consideration, then the most convenient position to effect a change of cross-section would be at the take-off points, e.g. at Q, X, Y, Z, X_1, X_2, . . , X_{L-1}, Y_1, Y_2, . . , Y_{M-1}, Z_1, Z_2, . . , Z_{N-1}.

DESIGN MODEL

The design model to be considered, from which a general formula could be obtained, is shown in Fig. 2.

It consists of a busbar run with lateral take-offs at X, Y, Y_1 .... Y_{N-1} and lateral take-off currents i_1, i_2, i_3 .... i_{N+1} respectively.

Closer examination reveals that the design model is part of the distribution system

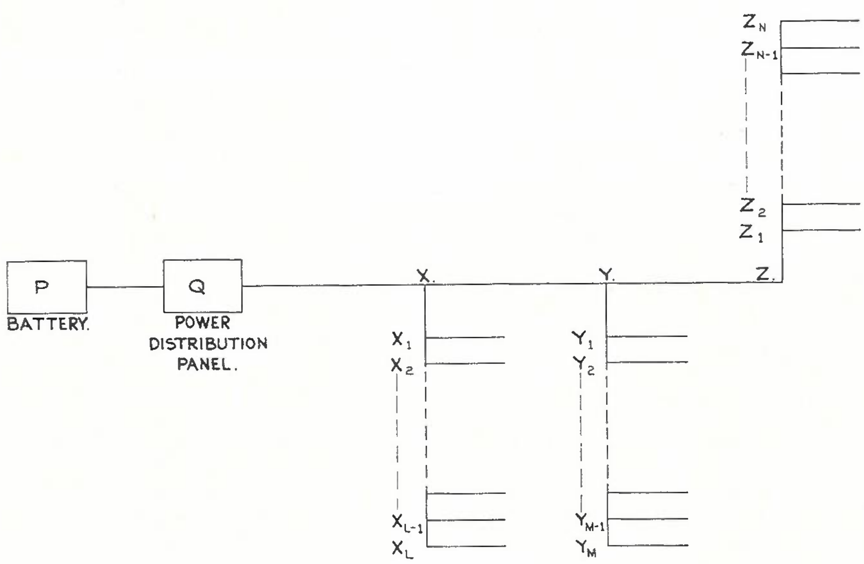

Fig. 1. — General System.

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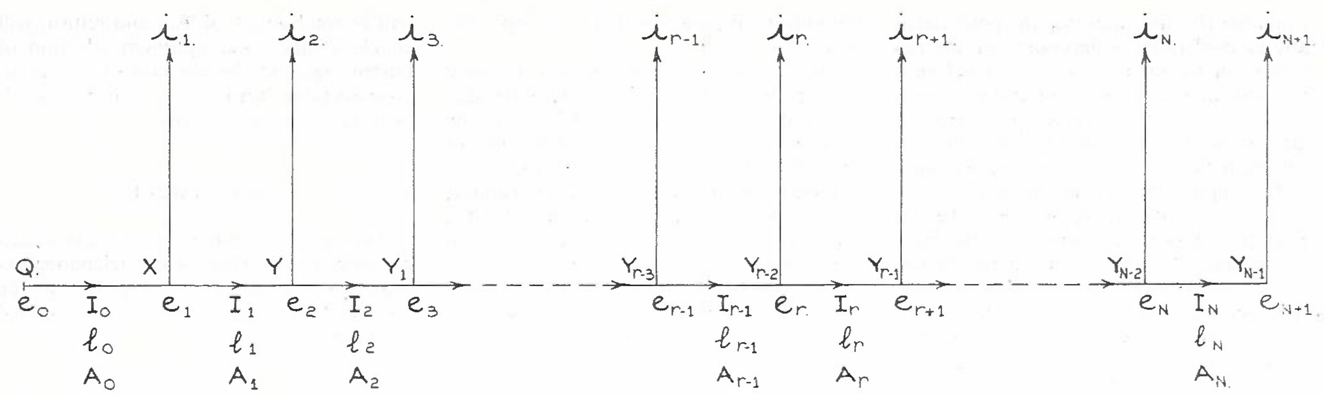

Fig. 2. — Design Model.

shown in Fig. 1. Then QXY would be part of the main busbar run and Y, Y_1, Y_2 .... Y_{N-1} the submain with lateral take-offs at Y_1, Y_2, Y_3 .... Y_{N-1} feeding into the various suites. In this manner it is possible to reduce a composite system into several simple systems.

In Fig. 2, the potential at Q is e_0, at X is e_1, and so on, till at Y_{N-1} it is e_{N+1}. For a general section, say $Y_{r-2} - Y_{r-1}$, I_r is the current flowing in that section, l_r the length, and A_r the cross-sectional area.

Applying Kirchoff's Law, it is simple to deduce the following current relationship at Y_{r-2}:—

$$I_{r-1} = I_r + i_r \quad \ldots\ldots\ldots (1)$$
$$r = 1, 2, \ldots\ldots N$$

At $\quad Y_{N-1}, I_N = i_{N+1}$

CURRENT CALCULATION

At this point, it is required to know the values of the lateral take-off currents, i's. For take-offs that feed into equipment suites, the i's are calculated by adding the various current drains per rack and multiplying by a utility factor* of 0.5 to 0.7; and for take-offs that feed into another submain busbar runs the i's would be the sum of the current drain of the suites fed by the submain. These can be obtained if the equipment layout of the exchange is available. Otherwise, it is necessary to assume an estimated ultimate current drain for these submains.

* The current drain per rack as given in P.M.G. Dept. Drawing No. CE90069, is the peak current load, and the utility factor is introduced to account for the fact that in any suite, not all the racks are drawing peak current load simultaneously.

DESIGN THEORY

From Fig. 2, consider the r^{th} and $(r + 1)^{th}$ sections of the busbar run, which are redrawn in Fig. 3,

Voltage drop across

$Y_{r-1} - Y_{r-2} = e_{r+1} - e_r = V_r$, say

and that across

$Y_{r-2} - Y_{r-3} = e_r - e_{r-1} = V_{r-1}$

Since I_r flows in the section $Y_{r-1} - Y_{r-2}$,

$$V_r = I_r R_r \quad \ldots\ldots\ldots (2)$$

where R_r is the resistance of the section $Y_{r-1} - Y_{r-2}$ whence

$$R_r = \rho \frac{l_r}{A_r} \quad \ldots\ldots\ldots (3)$$

where ρ = resistivity of busbar material = constant.

Substituting (3) into (2)

$$V_r = \rho \frac{l_r I_r}{A_r} \quad \ldots\ldots\ldots (4)$$

Similarly $\quad V_{r-1} = \rho \dfrac{l_{r-1} I_{r-1}}{A_{r-1}} \quad \ldots\ldots (5)$

Now cost of busbar $\propto$ volume of busbar (Area $\times$ Length) and for the section $Y_{r-1} - Y_r$

$$\text{Cost } C_r \propto A_r l_r \quad \ldots\ldots\ldots (6)$$

Substituting for A_r from (4)

$$Cr \propto \frac{I_r l_r^2}{V_r} \quad \ldots\ldots\ldots (7)$$

If the total cost of the whole busbar run is C

$$C = \sum_{r=0}^{N} Cr$$

Therefore $\quad C \propto \displaystyle\sum_{r=0}^{N} \frac{I_r l_r^2}{V_r} \quad \ldots\ldots\ldots (8)$

Differentiating C with respect to e_r

$$dC = \sum_{r=1}^{N} \frac{\partial c}{\partial e_r} de_r \quad \ldots\ldots (9)$$

For minimum cost

$$\frac{\partial c}{\partial e_r} = 0,$$
$$r = 1, 2, 3, \ldots, N$$

Assuming e_r variable and the others constant, then

$$\frac{\partial C}{\partial e_r} = \frac{\partial C}{\partial V_{r-1}} \cdot \frac{\partial V_{r-1}}{\partial e_r} + \frac{\partial C}{\partial V_r} \cdot \frac{\partial V_r}{\partial e_r} = 0 \quad (11)$$

Therefore, from equation (8)

$$-\frac{l_{r-1}^2 I_{r-1}}{V_{r-1}^2}(+1) - \frac{l_r^2 I_r}{V_r^2}(-1) = 0$$

i.e. $$\left(\frac{V_r}{V_{r-1}}\right)^2 = \frac{l_r^2 I_r}{l_{r-1}^2 I_{r-1}}$$

$$\frac{V_r}{V_{r-1}} = \frac{l_r \sqrt{I_r}}{l_{r-1}\sqrt{I_{r-1}}}$$
$$= K_r, \text{ say} \quad \ldots\ldots (12)$$
$$\text{for } r = 1, 2, \ldots, N.$$

(N.B. For r = 0, define $K_0 = 1$, for convenience.)

i.e. $$\frac{V_r}{V_{r-1}} = \frac{e_{r+1} - e_r}{e_r - e_{r-1}} = K_r \quad (13)$$

Simplifying,

$$e_r = e_{r+1} + \frac{K_r}{K_r + 1}(e_{r-1} - e_{r+1}) \ldots (14)$$

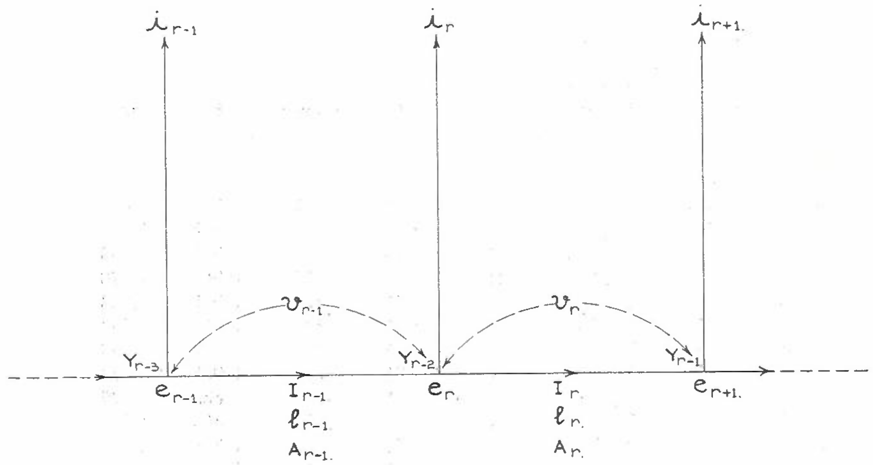

Fig. 3. — rth and r+1th Sections.

Equation (14) indicates that the potential at any take-off point is dependent on the potentials of the take-off points just before it and just after it. Thus, if the end potentials are known, e_r can be solved, however, for large number of take-offs the procedure of solving for e_r can be involved and tedious.

To simplify the evaluation of e_r, an assumption is made regarding one of the end potentials. Since it is known that the basis (a) would be the controlling factor, $e_0 - e_{N+1}$ is fixed and known. The assumption then is to consider e_r relative to one end potential and making that end potential equals 0. In this discussion, make $e_{N+1} = 0$. (N.B. This is equivalent to making the actual potential at Y_{N-1} the zero reference, and all other potentials relative to this new zero reference.) Using this assumption, the solution for e_r becomes

$$e_r = \frac{\sum_{i=0}^{N-r}\left[\prod_{j=0}^{r+i} K_j\right]}{\sum_{i=0}^{N}\left[\prod_{j=0}^{i} K_j\right]}\, e_0 \quad \ldots\ldots (15)$$

$r = 0, 1, 2, \ldots, N$

For derivation see Appendix A.

To calculate A_r, equation (4) is used.

$$A_r = \frac{\rho l_r I_r}{V_r} = \frac{\rho l_r I_r}{e_{r+1} - e_r}$$

$$= \frac{\rho l_r I_r}{e_0} \cdot \left\{ \frac{\sum_{i=0}^{N}\left[\prod_{j=0}^{i} K_j\right]}{\sum_{i=0}^{N-(r+1)}\left[\prod_{j=0}^{r+1+i} K_j\right] - \sum_{i=0}^{N-r}\left[\prod_{j=0}^{r+i} K_j\right]} \right\}$$

Simplifying

$$A_r = \frac{\rho l_r I_r}{e_0} \cdot \frac{\sum_{i=0}^{N}\left(\prod_{j=0}^{i} K_j\right)}{\prod_{j=0}^{r} K_j} \quad \ldots\ldots\ldots\ldots (16)$$

$r = 0, 1, 2, \ldots, N.$

For large value of N, equation (16) lends itself to calculation on a digital computer. Appendix B illustrates the flow chart and programme instructions for its solution on the Olivetti Programma 101 desk top computer.

The next step now is to consider the value of e_0 to be used. If in Fig. 2, Q is the d.c. power distribution panel and Y_{N-1} is the most remote suite power distribution box of the submain busbar, then the maximum voltage drop allowable, as given in Table 1, is 750 mV. Whereas, in equation (16), if l_r represents the length of the busbar section (i.e. half total length of lead and return) e_0 would then be 375 mV.

Having obtained the cross-sectional area, a plot of A_r vs length of busbar run (i.e. half of total length of lead and return) will enable a quick and optimum selection of busbar size and the position of change of cross-sectional area from a range of available standard busbar sizes.

AN EXAMPLE

As an example, the design of the new busbar system at a Queensland telephone exchange is considered here. Fig. 4 shows the estimated ultimate system, and estimated ultimate current loads.

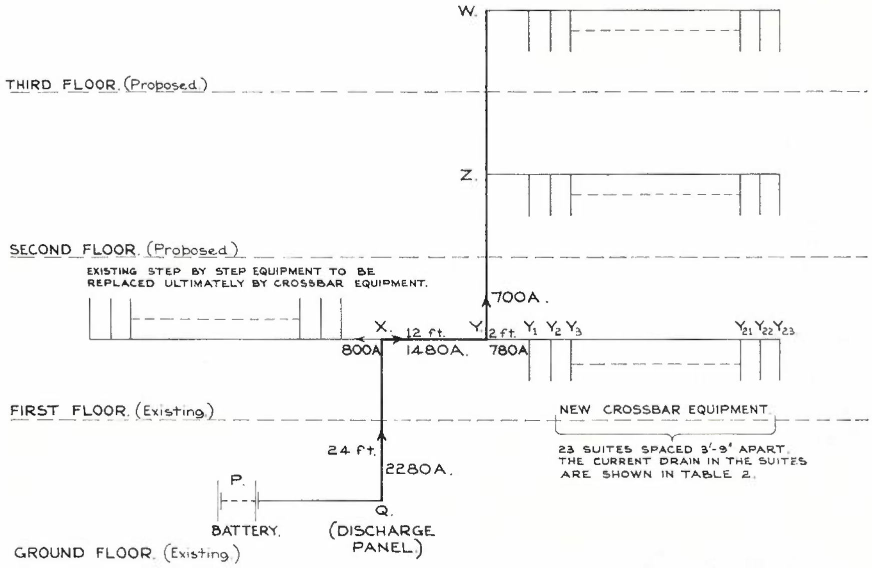

Fig. 4. — Estimated Ultimate Power Distribution System for a Queensland Exchange.

Initially, the design is done for busbar run $QXYY_1Y_2Y_3 \ldots . Y_{23}$. Subsequent design on the other submain distribution runs may be iterated by making use of potential calculated at X or Y and so on, and bearing in mind the maximum allowable voltage drop. Table 2 shows the results and Fig. 5 shows the plot of area of busbar cross-section versus busbar run, for aluminium busbars.

To facilitate selection of busbar sizes, the cross-section areas of available standard aluminium busbars are drawn in on Fig. 5. Hence, ignoring possible practical difficulties and assuming that all the standard sizes are used, the tapered busbar design could then be specified as: two 6 in × ½ in from Q to Y, two 4 in × ½ in from Y to Y_3, one 6 in × ½ in from Y_3 to Y_{16}, one

TABLE 2: RESULTS

Busbar Section	r	l ft.	I amps	K	A sq. in	Busbar Section	r	l ft.	I amps	K	A sq. in
QX	0	24	2280	1.0	5.477						
XY	1	12	1480	0.403	4.414	$Y_{11}Y_{12}$	13	3.75	441	1.0	2.410
YY_1	2	2	780	0.121	3.207	$Y_{12}Y_{13}$	14	3.75	413	0.968	2.332
Y_1Y_2	3	3.75	750	1.836	3.141	$Y_{13}Y_{14}$	15	3.75	385	0.965	2.253
Y_2Y_3	4	3.75	708	0.972	3.052	$Y_{14}Y_{15}$	16	3.75	357	0.963	2.170
Y_3Y_4	5	3.75	686	0.984	3.004	$Y_{15}Y_{16}$	17	3.75	329	0.960	2.083
Y_4Y_5	6	3.75	650	0.973	2.924	$Y_{16}Y_{17}$	18	3.75	301	0.957	1.993
Y_5Y_6	7	3.75	607	0.966	2.826	$Y_{17}Y_{18}$	19	3.75	273	0.952	1.898
Y_6Y_7	8	3.75	571	0.970	2.741	$Y_{18}Y_{19}$	20	3.75	225	0.908	1.723
Y_7Y_8	9	3.75	525	0.959	2.629	$Y_{19}Y_{20}$	21	3.75	177	0.887	1.529
Y_8Y_9	10	3.75	497	0.973	2.558	$Y_{20}Y_{21}$	22	3.75	129	0.854	1.305
Y_9Y_{10}	11	3.75	469	0.971	2.485	$Y_{21}Y_{22}$	23	3.75	86	0.816	1.066
$Y_{10}Y_{11}$	12	3.75	441	0.970	2.410	$Y_{22}Y_{23}$	24	3.75	43	0.707	0.784

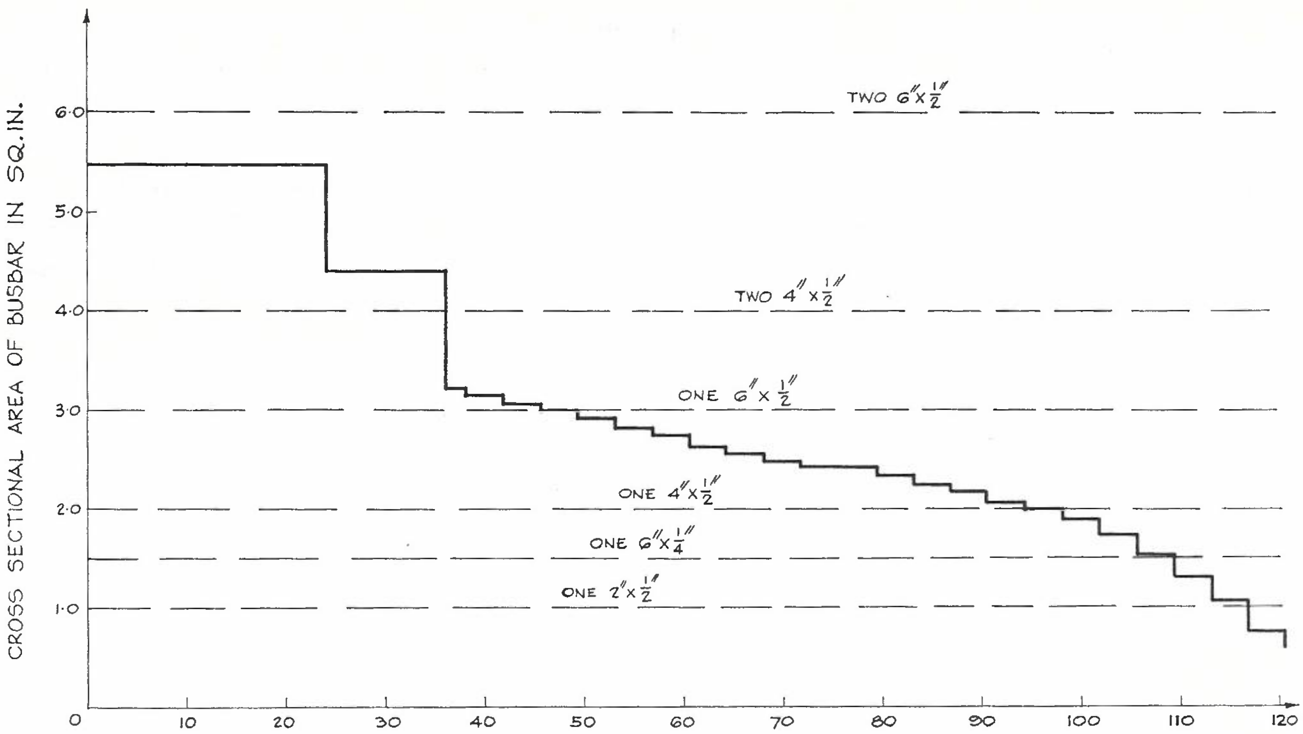

Fig. 5. — Plot of Busbar Cross Sectional Area Versus Length of Busbar Run in Example Considered.

4 in × ½ in from Y_{16} to Y_{20}, one 6 in × ¼ in from Y_{20} to Y_{22} and one 2 in × ½ in from Y_{22} to Y_{23}. However, in adopting such a specification the assembly and installation of such a system can become difficult, thus increasing the cost and nullifying the economic advantage. A compromise, therefore, must be reached to obtain a specification that keeps assembly and installation simple and maintains an optimum design. To achieve this one of the following selections can be adopted:—

(a) Two 6 in × ½ in from Q to Y, one 6 in × ½ in from Y to Y_{16}, and one 4 in × ½ in from Y_{16} to Y_{23}.

(b) Two 6 in × ½ in from Q to Y, two 4 in × ½ in from Y to Y_{16}, and one 4 in × ½ in from Y_{16} to Y_{23}.

In selection (a) above, there is no risk of exceeding the maximum allowable voltage drop since the busbars selected overprovide for a large part of the run.

A final point that needs to be mentioned is that busbars come in standard lengths and since cutting away sections of it represents waste, the final selection has to be tailored to minimise the waste.

SUMMARY OF DESIGN PROCEDURE

1. Construct the estimated ultimate power distribution system of the form shown in Figs. 1 or 4. The appropriate estimated ultimate current load in the various sections are inserted.
2. Using Fig. 4 as an example, the composite system is broken up into four simple systems similar in form to Fig. 2. This is shown in Fig. 6 below.
3. Design system in Fig. 6(a) first. Here $l_0 = 24$ ft, $I_0 = 2280A$; $l_1 = 12$ ft, $I_1 = 1480A, \ldots\ldots,$
$l_{23} = 3.75$ ft, $I_{23} = 43A$ (See Table 2). and $N = 24$, $e_0 = 375$ mV, $\rho = 0.01364$ m ohm/sq. in/ft.
Equation (12) enables the K_r's to be calculated and equation (16) or (30) enables the areas A_r to be calculated. A quick calculation of the K_r's and A_r's can be obtained using the computer programme instructions of Fig. 8 in Appendix B. In the first part of the programme, the K_r's are calculated by entering the input data l_r and I_r in the sequence $r = N, N-1, N-2, \ldots, 3, 2, 1, 0$. When the last l and I, i.e. l_0 and I_0, have been entered, all the K_r's and the D as defined in equation (29) would have been calculated and printed. Then proceed with the second

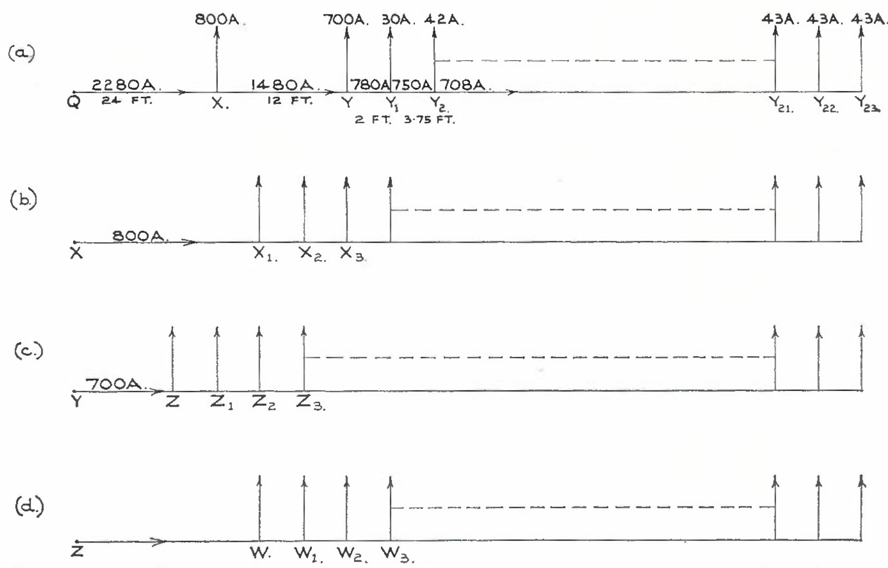

Fig. 6. — Reduction of Composite System into Four Simple Systems (a), (b), (c) and (d).

part of the programme to calculate the areas A_r by entering data l_r, I_r and K_r in the reverse sequence, i.e. $r = 0, 1, 2, \ldots, N$. Thus $A_0, A_1, A_2, \ldots, A_N$ will be obtained in this order.

4. From the above results, the potentials at X, Y or any other points can be calculated. The potential at X gives the corresponding value of e_0 for the design of system of Fig. 6(b); and similarly, the potential at Y gives e_0 for the design of system in Fig. 6(c). From the design of system in Fig. 6(c) the potential obtained at Z enables design of system in Fig. 6(d).
5. Having obtained the areas, a plot of A_r vs length of run (i.e. half total length of lead and return) is made to enable practical selection of busbar sizes. In the example considered, i.e. system in Fig. 6(a), the specification is two 6 in × ½ in aluminium busbars from Q to Y, one 6 in × ½ in busbar from Y to Y_{16} and one 4 in × ½ in busbar from Y_{16} to Y_{23}. From Fig. 5 it is evident that two 6 in × ½ in busbars in sections Q to Y represents an overprovision in design. From this it can be deduced that a shorter length of the one 6 in × ½ in busbar section would be needed. To check on this, the procedure is reiterated from Y to Y_{23} using the potential at Y to be e_0.

(N.B. Figs. 6, (b), (c) and (d) have not been fully dimensioned because present design is emphasised in Fig. 6(a) only.)

CONCLUSION

In this paper, a general analytical approach to the optimum design of tapered busbar systems is presented. Although, in the method, it is initially assumed that the busbar run is tapered at a large number of sections, the final design specification involves a relatively small number of cross-sectional area changes to maintain simplicity in assembly and installation. Moreover, the method lends itself to calculation on a digital computer. In short, it offers a quick and reliable solution.

ACKNOWLEDGMENT

The author thanks his colleagues in Brisbane for their helpful discussion and constructive criticisms during preparation of this paper.

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APPENDIX A
DERIVATION OF e_r

Rewriting equation (14),

$$e_r = e_{r+1} + \frac{K_r}{K_{r+1}}(e_{r-1} - e_{r+1}) \quad \ldots\ldots\ldots\ldots (14)$$

for $r = N$, $$e_N = e_{N+1} + \frac{K_N}{K_{N+1}}(e_{N-1} - e_{N+1})$$

Since $e_{N+1} = 0$ as assumed,

$$e_N = \frac{K_N}{K_{N+1}} \cdot e_{N-1} \quad \ldots\ldots\ldots\ldots (17)$$

for $r = N - 1$, $$e_{N-1} = e_N + \frac{K_{N-1}}{K_{N-1} + 1}(e_{N-2} - e_N)$$

Substituting for e_N and simplifying,

$$e_{N-1} = \frac{K_{N-1}(1 + K_N)}{1 + K_{N-1}(1 + K_N)} e_{N-2} \quad \ldots\ldots\ldots\ldots (18)$$

Repeating the procedure,

$$e_{N-2} = \frac{K_{N-2}(1 + K_{N-1}(1 + K_N))}{1 + K_{N-2}(1 + K_{N-1}(1 + K_N))} e_{N-3} \quad \ldots\ldots\ldots\ldots (19)$$

$$e_{N-3} = \frac{K_{N-3}(1 + K_{N-2}(1 + K_{N-1}(1 + K_N)))}{1 + K_{N-3}(1 + K_{N-2}(1 + K_{N-1}(1 + K_N)))} e_{N-4} \quad \ldots\ldots (20)$$

and so on. In general,

$$e_{N-p} = \frac{K_{N-p}(1 + K_{N-p+1}(1 + \ldots + K_{N-1}(1 + K_N)\ldots)}{1 + K_{N-p}(1 + K_{N-p+1}(1 + \ldots + K_{N-1}(1 + K_N)\ldots)} e_{N-p-1} \quad \ldots\ldots\ldots\ldots (21)$$

for $p = N - 1$

$$e_1 = \frac{K_1(1 + K_2(1 + \ldots + K_{N-1}(1 + K_N)\ldots)}{1 + K_1(1 + K_2(1 + \ldots + K_{N-1}(1 + K_N)\ldots)} e_0 \quad \ldots\ldots (22)$$

for $p = N - 2$

$$e_2 = \frac{K_2(1 + K_2(1 + \ldots + K_{N-1}(1 + K_N)\ldots)}{1 + K_2(1 + K_2(1 + \ldots + K_{N-1}(1 + K_N)\ldots)} e_1 \quad \ldots\ldots (23)$$

Substituting for e_1 from (22) into (23), and simplifying,

$$e_2 = \frac{K_1K_2(1 + K_3(1 + \ldots + K_{N-1}(1 + K_N)\ldots)}{1 + K_1(1 + K_2(1 + \ldots + K_{N-1}(1 + K_N)\ldots)} e_0 \quad \ldots\ldots (24)$$

Repeating the procedure

$$e_3 = \frac{K_1K_2K_3(1 + K_4(1 + \ldots + K_{N-1}(1 + K_N)\ldots)}{1 + K_1(1 + K_2(1 + \ldots + K_{N-1}(1 + K_N)\ldots)} e_0 \quad \ldots\ldots (25)$$

and so on. In general,

$$e_r = \frac{K_1K_2K_3\ldots K_r(1 + K_{r+1}(1 + \ldots + K_{N-1}(1 + K_N)}{1 + K_1(1 + K_2(1 + \ldots + K_{N-1}(1 + K_N)\ldots)} e_0 \quad (26)$$

Since K_0 has been defined to be equal to 1

$$e_r = \frac{K_0K_1K_2K_3 \dots K_r(1 + K_{r+1}(1 + \dots + K_{N-1}(1 + K_N) \dots)}{K_0(1 + K_1(1 + K_2(1 + \dots + K_{N-1}(1 + K_N) \dots)} e_0 \quad \dots\dots (27)$$

Using the Σ and Π notation,

$$e_r = \left[\frac{\sum_{i=0}^{N-r}\left(\prod_{j=0}^{r+i} K_j\right)}{\sum_{i=0}^{N}\left(\prod_{j=0}^{i} K_j\right)}\right] e_0$$

for $r = 0, 1, 2, \dots, N$

which is equation (15).

APPENDIX B

(a) Flow chart to calculate A_r in equation (16)

Let $D = \sum_{i=0}^{N}\left(\prod_{j=0}^{i} K_j\right)$

$$\text{i.e. } e_r = \frac{K_0K_1K_2 \dots K_r + K_0K_1K_2 \dots K_{r+1} + \dots + K_0K_1 \dots K_N}{K_0 + K_0K_1 + K_0K_1K_2 + \dots + K_0K_1K_2 \dots K_r + \dots + K_0K_1 \dots K_N} e_0 \quad \dots\dots (28)$$

$$= K_0 + K_0K_1 + K_0K_1K_2 + \dots + K_0K_1K_2 \dots K_r + \dots + K_0K_1K_2 \dots K_N$$

$$= K_0(1 + K_1(1 + K_2(1 + \dots + K_r(1 + \dots + K_{N-1}(1 + K_N) \dots) \quad \dots\dots (29)$$

Then equation (16) becomes

$$A_r = \frac{\rho l_r I_r D}{e_0 K_0 K_1 K_2 \dots K_r} \quad \dots\dots (30)$$

Fig. 7 shows the flow chart for use on the Olivetti 101 programma desk top computer.

(b) Computer Programme Instructions to Calculate A_r

Fig. 8 shows the programme instructions for use on the Olivetti Programma 101 desk top computer. Although programme is written with reference to the flow chart of Fig. 7, the limited capacity of the machine compels the programme to vary slightly from that of the flow chart.

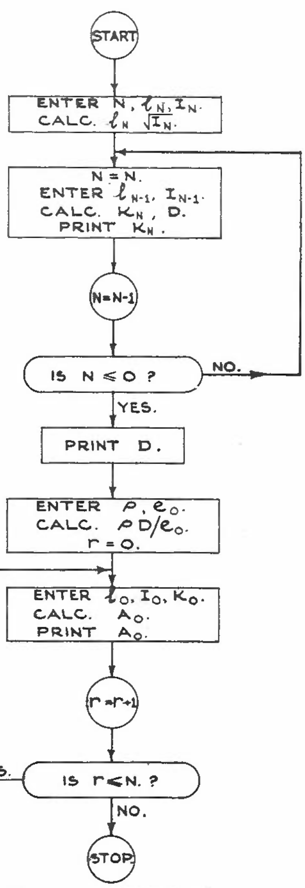

Fig. 7. — Flow Chart.

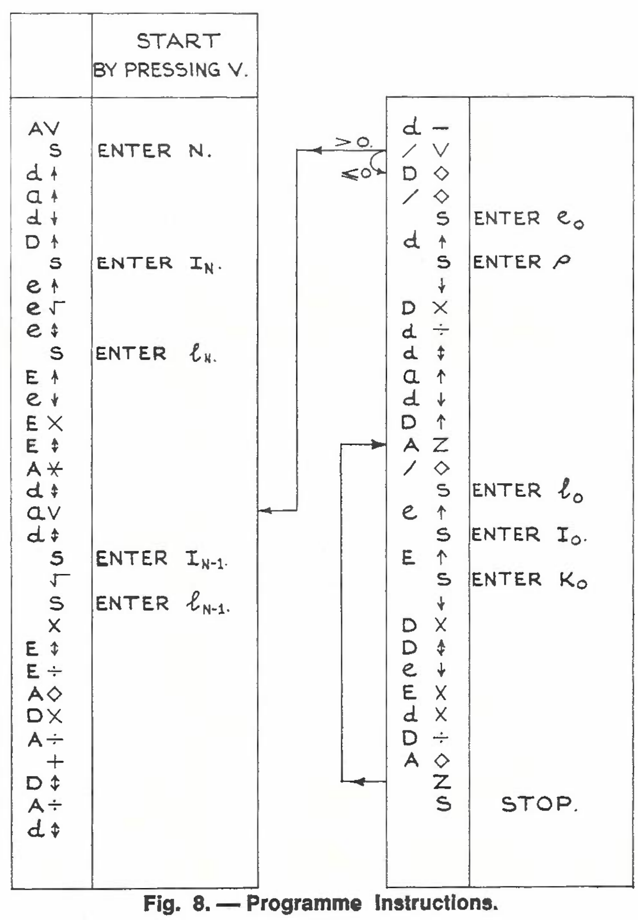

Fig. 8. — Programme Instructions.

ANTENNA MEASUREMENTS USING NATURAL RADIO SOURCES

*R. WIELEBINSKI, Ph.D.**

INTRODUCTION

Antenna performance can be specified in terms of parameters such as gain, complete power pattern, polarization response, phase characteristic or pointing accuracy, to mention only some of the more important parameters. The trend to large antenna apertures in such applications as satellite or space communications, and to low system noise temperatures, leads to the requirement of measuring the antenna performance to a high degree of accuracy. Even when an antenna has been installed, subsequent technological advances in the field of high efficiency feeds may require site testing of antenna performance.

Several standard methods have been used in antenna measurements with varying degrees of reliability being achieved. Transmitters located on high towers are often used to measure antenna polar patterns. To work in the far field of a large antenna, free from earth effects, very high towers are required. An alternative method employed in some instances is to fly a transmitter in an aircraft or a helicopter. Serious problems arise in this technique through the lack of knowledge of precise transmitter position, aircraft antenna interactions and, in the case of helicopters, by variations of atmospheric refraction. In both methods ground reflections add a further error in polar pattern measurements. Satellite-borne transmitters would be suitable for large antenna evaluation. However a far less expensive source of constant power may be found in the naturally occurring radio sources.

Radio sources are available in great abundance at low values of flux level. They are distributed over the whole sky and the flux values are known to a precision of some 10%. Selecting some 20 strong discrete sources for antenna measurements gives a very flexible calibrating system. A point which must not be overlooked is that many 'discrete' radio sources have a structure on the scale of minutes of arc. Furthermore some sources are somewhat linearly polarized. A criterion used for selection of suitable sources for antenna measurements must include the following points:

(i) Source intensity should be high.

(ii) Source should have small angular size.

(iii) Polarization of source must be known.

(iv) Source should be well clear of any potential sources of misinterpretation.

(v) Positional accuracy should be high.

On the basis of these criteria a list of suitable sources is presented in this paper. The sources have been obtained from catalogues with emphasis on accurate flux values at the quoted frequencies. Interpolation to any specific frequency should be possible. In addition to the table of sources the basic calibration procedures are described. Correlation techniques are described which allow some further advantage to be gained.

THE RADIATION RECEIVED BY AN ANTENNA

A discrete radio source of flux density **S** (watts metre^{-2} Hz^{-1}) produces a deflection in a matched receiver which corresponds to an aerial input temperature Ta given by (Ref. 1)

$$S = \frac{8\pi k Ta}{G\lambda^2} \qquad (1)$$

where k is Boltzmann's constant
λ is the wavelength
G is the antenna gain, measured with reference to an isotropic radiator.

In the above expression a factor of 2 has been included to take account of the fact that an aerial of one polarization accepts only ½ of power incident from a randomly polarized radio source. The expression (1) is equivalent to the Frijs transmission formula (Ref. 2), which is often used in far field intensity determinations.

An additional requirement of expression (1) is that the radio source be of small angular extent as compared to the antenna beam. If this is not the case, but if the source distribution is known a summation can be used to obtain the aerial temperature Ta′ by

$$Ta' = \sum_{r=1}^{n} T_r \, a_r \, p_r \qquad (2)$$

where T_r is the temperature of the r'th region
a_r is the area of the r'th region
p_r is the power polar pattern level.

The ratio of gain to system noise temperature ultimately determines the system performance which may be expressed as:

$$\frac{G}{T} = \frac{8\pi k}{\lambda^2 S} \cdot \frac{T_a + T_s}{T_s} \qquad (3)$$

where T_s is the system noise to temperature.

The parameter $\frac{G}{T}$ is the recommended measure of the system performance as used by the CCIR (Ref. 3). The measurement of the antenna performance as specified in expression (3) can be a relative measurement. The measurement can be made with the aerial pointing first away from the radio source used as a calibrator and later with the source in the main beam. This allows the determination of the ratio r:

$$r = \frac{T_a + T_s}{T_s}$$

and as a result if the radio source flux S is known G/T can be determined.

STANDARDS OF NOISE

The basic standard of random noise is the thermal noise output from a resistor. A matched termination immersed in liquid nitrogen provides an output noise voltage which is equivalent to some 77°K (a higher noise voltage may result from loss in the connecting transmission line if it is at a higher temperature than the termination). A system of accurate noise deflections can be provided by the use of calibrated, matched attenuators. From elementary noise considerations the total effective noise T_e to a receiver from a termination at temperature T_t after insertion of a lossy component at temperature T_o, with attenuation (power ratio) α is given by

$$T_e = \alpha T_t + (1 - \alpha) T_o \qquad (4)$$

In a calibration it is usual to measure first a deflection when a matched termination in liquid nitrogen is connected to the receiver and another with an attenuator inserted between the termination and receiver. The difference in deflections ΔT (if a square law detector is used) is

$$\Delta T = (1 - \alpha)(T_o - T_t) \qquad (5)$$

Thus for a 1dB attenuator ($\alpha = 0.794$) at ambient temperature ($T_o = 293°K$) with a liquid nitrogen termination ($T_t \simeq 79°K$) a noise step ΔT of 44°K is obtained.

A typical switched calibration receiver used in radio astronomy is shown in Fig. 1. Matching on the aerial and reference termination sides is achieved by use of a signal generator and a reflection technique. In this receiver initially two accurate hot-cold terminations (Ref. 4) are used to replace the aerial and termination T1. Adjustments are made to matching unit MU3 to receive zero reflected signal. In future matching procedures either on the aerial side, or reference termination side, null techniques allow accurate matching. However an unswitched receiver can be used with some loss of stability.

A set of 1, 2 and 3dB high precision attenuators used in conjunction with a

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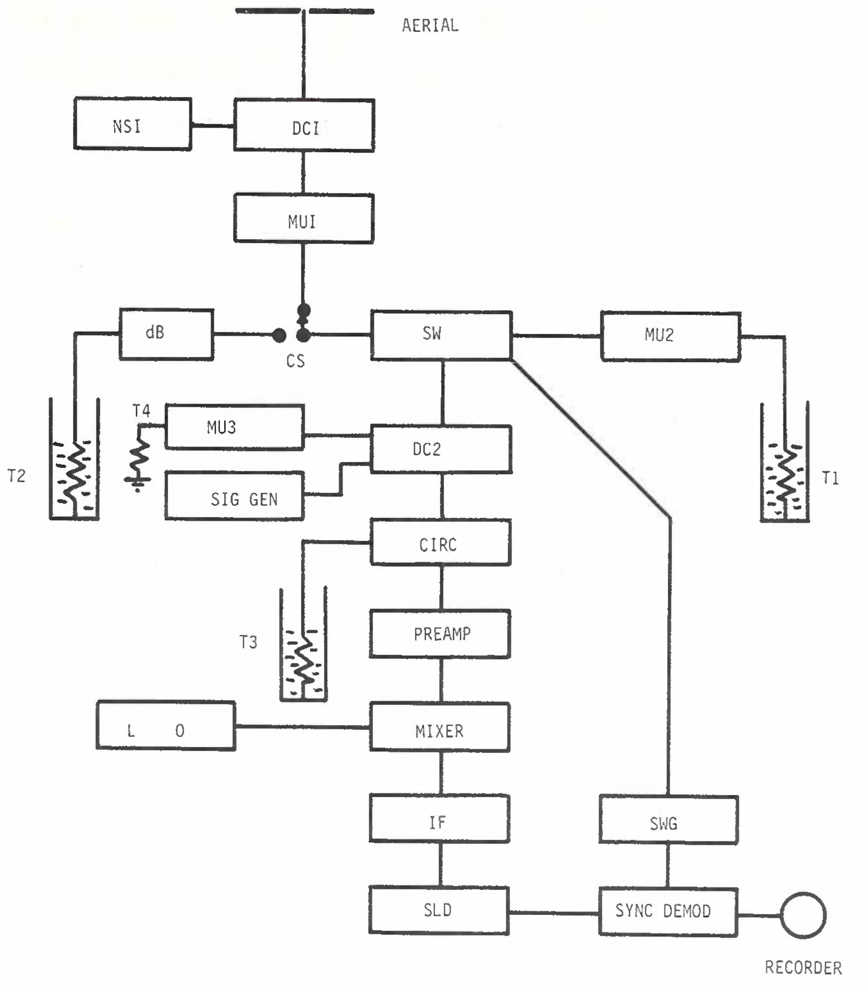

DC1, DC2	Directional couplers	CIRC	Circulator
NS1	Noise source	PREAMP	Preamplifier
MU1, MU2, MU3	Matching units	LO	Local Oscillator
T1, T2, T3	Liquid nitrogen terminations	IF	IF amplifier
T4	Termination	SLD	Square law detector
dB	Calibrating attenuators	SWG	Switching waveform generator
CS	Coaxial switch	SYNC DEMOD	Synchronous demodulator
SW	Comparison switch		

Fig. 1. — A Switched Receiver Used for Antenna Cabibration

liquid nitrogen termination allows the calibration of secondary noise sources, over some 200°K temperature range. Secondary noise sources available are either noise diodes or noise discharge tubes. A concise literature exists covering the properties of noise sources (see Refs. 5 and 6). The principal conclusion is that commercial noise sources require calibration against thermal noise from resistors before use in antenna measurements.

In a typical noise calibrating procedure the deflection of a noise source through a directional coupler is calibrated against noise power increments due to attenuator insertion. In this way the secondary noise source becomes an absolute noise standard to a high degree of accuracy. This procedure eliminates one of the main sources of erroneous calibration results.

THE CALIBRATING SOURCES

For beam pattern derivation, strong sources of small angular size, clear of other sources (including the galactic background) are required. For positional accuracy, sources of small angular size with accurately known positions are required. The strongest radio sources Cassiopea A, Cygnus A or Taurus A have a number of features which make them undesirable as antenna calibrators. Cassiopea A is only available to northern latitude stations as well as having a slowly decreasing flux. Cygnus A is just visible from southern latitudes but is observed on a complex background. All the eight strongest sources have angular diameters of 3′ to 5′ with complex distributions within this area. Some of the sources are linearly polarized to a small degree.

Table 1 has been drawn up using basically a series of Parkes catalogues (Ref. 7). The source positions given in the first three columns are in 1950 co-ordinates. These positions change annually and precession using an astronomical ephemeris is necessary for accurate work. The following columns give source flux values at a number of frequencies. The maximum source angular size is listed along with polarization data. Sources are listed under the catalogue designation but common names are also given in the last column.

OTHER ANTENNA MEASUREMENTS

The foregoing discussion covered the basic calibration of antenna gain. This, being the most important parameter, is of prime interest to an antenna engineer. System performance of calibration giving the $\frac{G}{T}$ parameter was also sketched out. There are however a further number of measurements possible which may be required.

The measurement of the total polar pattern is often desirable particularly for the purpose of determination of sidelobe structure. This can be done partly using the Sun as a source of power. However the method of correlation measurement allows the derivation of the voltage polar pattern which permits sidelobe measurements down to -30dB or more although a second antenna is required for this measurement (see Ref. 8). Polarization measurements can also be made using voltage correlation methods.

Further advantage in absolute gain determinations can be obtained by the use of a standard gain antenna (such as a horn) in conjunction with the test antenna, (Ref. 9). These measurements are of particular interest in the determination of absolute flux values.

SOURCE DETECTABILITY

Strong radio sources are easily detected with present low noise receivers using antennas 45ft diameter or more. Weaker sources require larger antennas and better receivers. Conversely, given a dish diameter and a receiver of a particular noise figure, a limit is set on sources usable for calibrations. It is

TABLE 1

Source	Right Ascension (1950)	Declination	S — flux units $10^{-26} W\,m^{-2}\,sec^{-1}$ 1 85MHz	2 150MHz	3 408	4 1420	5 2.7GHz	6 5GHz	7 8GHz	Size	Polarization	Remarks
0320–37	03h20m42s	−37° 25′	950	475	177	—	935	—	—	20′	10%	Fornax A
0518–45	05 18 24	−45 50	570	343	117	52	32	—	—	5′	3%	Pictor A
0539–01	05 33 11	−01 56	—	—	37	51	56	—	—		.2< %	
3C144	05 31 31	+21 59	1700	1600	1150	850	750	—	573	5′		Taurus A
3C145	05 32 51	−05 25	69	42	177	281	51	—	—	4.5′	1< %	Orion nebula
0916–12	09 15 43	−11 53	580	340	110	36	25	13	9	5′	.2< %	Hydra A
3C273	12 26 34	+02 19	167	150	49	38	41	38	28		2.5	Some variability
3C274	12 28 17	+12 40	1800	1015	510	197	143	57	44	4.7′	0.1<	Virgo A
3C348	16 48 42	+05 04	890	420	142	43	23	12	7	3.2′	5%	Hercules
1717–00	17 17 56	−00 56	475	325	116	49	30	16	14	4′	6%	3C353
3C405	19 57 45	+40 36	14000	10000	4700	1400	750	—	200	2.3′		Cygnus A
2152–69	21 52 58	−69 56	253	114	60	26	16	10	—	4′	4%	
3C461	23 21 11	+58 33	18500	12000	5500	2200	1300	—	590	4′		
2356–61	23 56 29	−61 12	296	66	49	19	11	—	—	4′	5%	

normal to set the minimum detectable temperature deflection as

$$\Delta T \min = 5\,M \frac{Tsys}{(\Delta f\,\tau)^{\frac{1}{2}}}$$

where Tsys is the system noise temperature
Δf is the receiver bandwidth
τ is the time constant ($\tau \simeq 2.2RC$ for a integrating filter)

and M is a factor which equals 1 in unswitched receivers, and equals 2 in a switched receiver. From the antenna diameter the antenna source temperature may be estimated. From the knowledge of receiver characteristic the minimum detectable deflection can be predicted. The use of wider bandwidth and longer time constant allows the detection of weaker sources with an antenna of particular gain. Using the information on source fluxes given in Table 1 or of weaker sources (Ref. 7) an antenna calibration procedure can be established for an antenna relying only on naturally occurring radio sources.

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THE INTRODUCTION OF ELECTRONIC DEVICES INTO ELECTROMECHANICAL TELEPHONE EQUIPMENT

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INTRODUCTION

In existing telephone equipment, the switching elements consist of electro-mechanical switches such as relays, selectors and crossbar switches. Apart from their proven reliability, these switches are slow in operation, inefficient in their inter-connection, large in size and consume a large amount of power.

The great success of electronic components in transmission equipment and in electronic computers has stimulated the development of electronic exchanges. This in turn has caused an increasing interest in the use of electronic devices in new units to be introduced into the existing network. In the introduction of these units into the existing networks, new problems arise on the electrical level; the incompatibility of electronic devices with the existing operating conditions and the reliability of electronic components in the environment of the existing equipment are the main problems to be considered. On the network level, the electronic units may have been developed with a new system philosophy which may be incompatible with the system philosophy of the existing equipment. This paper examines the general principles to be followed in using sensitive electronic devices in the existing equipment and describes an illustrative model in which the principles are demonstrated. The model is an electronic version of the outgoing junction relay set FUR-T5F-H. (Australian Post Office PCM Signalling Relay Set, Ref. 1)

INTERFACE PROBLEMS

The problems encountered in introducing sensitive electronic components into the existing equipment can generally be grouped under one heading, namely the interface problems.

On one side we have the existing network, working at a high voltage, with a relatively slow speed and an electrically noisy environment. On the other side we have advantages offered by the latest electronic components such as fast operation, small size and low power operation. These advantages, however, are accompanied by the noise susceptibility of the devices.

The problem is, how to ensure a reliable operation of any electronic unit without losing the advantages offered by it.

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GENERAL APPROACH

There are several approaches which may be taken in finding an economic solution to the above problems:—

(i) To modify the existing operating conditions to suit the new units. This may take the form of identifying the sources of noise and eliminating the noise.
(ii) To adapt the proposed new units to work satisfactorily under the existing operating conditions.
(iii) To employ an interface network between the existing equipment and the new unit. This requires no modification of the existing system and allows full use of the advantages offered by the new devices.
(iv) To find a compromised solution of the first three approaches.

In most cases the last approach gives the most satisfactory solution. This, however, requires a thorough knowledge of the two systems and the environment under which the existing equipment is working satisfactorily.

In general the approach can be summarised as follows:—

1. Define the functions of the unit. This should be as general as possible, so that a maximum amount of flexibility can be incorporated into the design.
2. Assess the environment under which the new units are to provide a satisfactory service. This should involve the improvement of the environment wherever possible. Worst case conditions should be established. (Ref. 2)
3. Design the units, perhaps with interface elements incorporated in the units, with the view of maximum reliability under the conditions defined in (2). New techniques may have to be developed to ensure reliable operation.
4. Assess the performance of a unit in the real working conditions before the unit is fully accepted.

FUR-T5F-H RELAY SET USING ELECTRONIC DEVICES

This signalling equipment is designed for use at ARF crossbar exchanges to signal over junctions having two separate signalling paths distinct from the speech path. (Ref. 1) This condition is usually met by derived channels using Pulse Code Modulation (PCM). This relay set can be used on junctions operating in the modified Karlson mode or in the switch hook mode. A detailed description of these signalling schemes is given in Ref. 3.

The general functions of the relay set are:—

(i) To be seized from a group selector and to busy the junction against intrusion from other calls.
(ii) To transmit the seized condition to the distant end.
(iii) To give satisfactory repetition of loop disconnect impulsing to the distant end.
(iv) To indicate answer condition by reversal of the line polarity, and restore normal polarity when the B party clears.
(v) To transmit metering signals to the calling party on multi-metered calls.
(vi) To release the distant end when the calling party clears.
(vii) To be busied against seizure if a fault occurs in the transmission system or the distant end equipment is taken out of service for maintenance.
(viii) To repeat a forced release signal if such a signal is received from the distant end.

Assessment of the Working Conditions

As the conventional exchange supply voltage is unsuitable for most commercially available integrated circuits, the electronic relay set has been designed to work from a separate low voltage power supply. This necessitates the use of interface elements, e.g. fast operating miniature reed relays.

The environment under which the unit is to operate was investigated by measuring the noise in the peripheral equipment. Continuous noise (high frequency) amplitude as high as 100mV has been observed on some wires.

Impulse noise spikes of 200 volts amplitude have to be allowed for.

The proposed unit therefore, must be immune to those types of noise. By using delay circuits at the input and output wires, and electrically isolating the units from the external world by using reed relays and good shielding, the effects of noise can be minimised.

Logic Diagram

The main advantages offered by the electronic devices to be incorporated in this unit are the smallness in size and the faster speed of operation, the latter making possible a reduced toler-

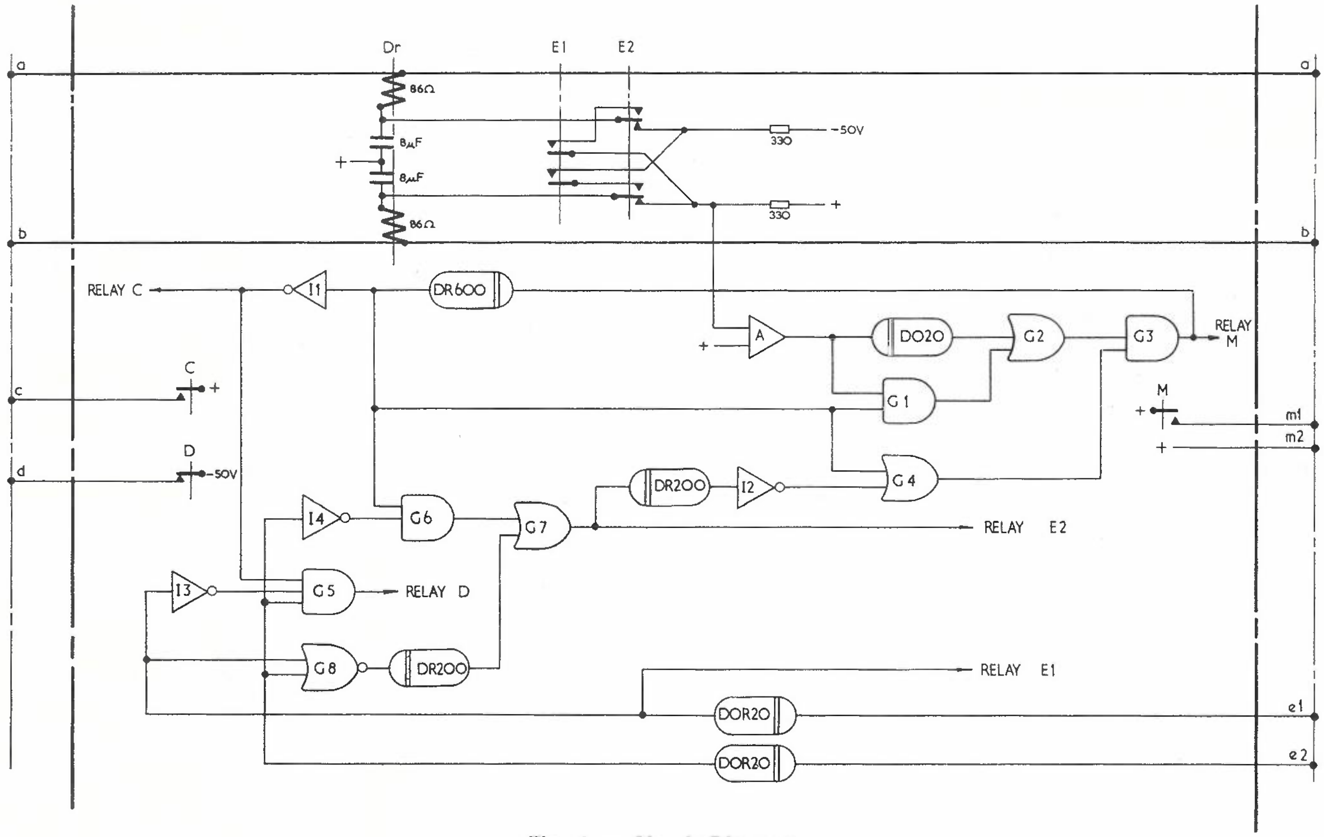

Fig. 1. — Circuit Diagram.

ance of the timing of signals. The present signal timing tolerance is as high as ∓20% which is determined by the tolerance of the commercially available timing relays. The unit to be described here is to function in exactly the same way as the electromechanical version. A logic diagram is shown in Fig. 1, and the following description refers to this figure.

The retard coil Dr is required to provide a high impedance path to speech signals, and forms the conventional relay set transmission bridge.

Idle Conditions (power applied):

a, b wires open
ground disconnected from c wire
-50V applied to d wire
ground disconnected from m1 wire
ground applied to m2 wire
e1 is open
e2 is grounded.

Seizure: The loop on a, b wires develops a negative voltage at the left-hand end of R2, the lower 330 ohm resistor in Fig. 1. This negative voltage is inverted through the high input impedance operational amplifier (A). If the loop lasts longer than 20 mS, the loop condition transmitted through the gates (G_1 and G_3) operates the reed relay M. The operation of the relay M applies earth onto the wire m1.

The voltage at the output of G_3 is returned through the delay release element (DR600) to the input of the AND gate G_1; this opens the gate G_1 which bypasses the delay element DO20. This arrangement prevents the dial pulses from being distorted through DO20.

The seize condition is transmitted through the inverter I_1 which operates relay C which applies earth onto wire c. This also releases relay D through the AND gate G_5, hence breaking the d wire circuit.

On pick up of the FIR, earth is returned on the e1 lead. This condition is tested by the DOR 20. If it lasts longer than 20 mS, the relay E1 operates.

MFC signalling: This may now proceed. Dialling may also occur and if so the dial pulses will be transmitted through the amplifier A and the gates G_1, G_2 and G_3 onto the relay M which will repeat the dial pulses on the wire m1. The dial pulses are prevented from affecting the rest of the circuit by the delay release element DR600.

Answer: On answering, the earth on e2 is disconnected. After the persistence test by the DOR20 is satisfied, the answer condition is transmitted through the inverter I_4 and the gates G_6 (which has been opened by the seizure condition), and G_7 to operate relay E2. The operation of E2 reverses the polarity of the wires a, b.

Meter or B-Party Clear: Metering on a multi-metered call, or B-party clear on a unit fee local call, returns earth on to wire e2. This condition releases the relay E2 which returns normal polarity to the wires a, b. This condition also prepares the gate G_5 for the restoration of relay D.

A-party Clear: When the A-party clears, the loop condition on the wires a, b is broken. This condition, via the gates G_1, G_2 and G_3 releases the M relay which disconnects the earth from wire m1. When the persistence test of this condition by DR600 has been satisfied, the gate G_5 is prepared via I_1, relay C is operated which applies earth onto the c wire, and relay E2 is released via the gates G_6 and G_7. After E2 has been released, G_3 is closed for a period of 200 mS determined by the DR200, via I_2 and G_4. This allows the line to go back to normal polarity without a momentary line charging current being registered as seizure condition.

PARAPAK — Electronic Devices

When the corresponding FIR has cleared, wire e1 is opened and wire e2 is earthed. Relay D then operates and the FUR is marked idle to accept further calls.

Force Release: A force release signal may be received after answer. This disconnects earth from e1 and hence releases E1, and the loop condition on the wires a, b is interrupted. This condition disconnects the earth from wire m1 as described for the clear forward operation. FIR will release after 300-450 mS which is the recognition time of a force release signal. This may result in an idle condition being returned (e2 earthed) but while e1 and e2 are both open circuited, an output will exist on the NOR gate G_8 which ensures that E2 remains operated; in the case of idle condition being returned, E2 will remain operated for a period of 200 mS, to ensure a correct transmission period of the force release signal (480-720 mS). When the output of DR600 disappears, d wire is restored to normal and E2 releases.

The FUR then returns to normal.

Blocking: In the idle condition, if e2 releases (opens), the d-wire circuit is broken, thus blocking the FUR out of traffic.

Fault: A transmission system fault will result in both e1 and e2 being open circuited. This will cause blocking if the FUR is idle and force release after a call has matured. Before answer a fault will have no effect in the FUR until the A-party clears forward.

Circuit Realisation

The experimental unit has been built using commercial integrated circuits for the gates and inverters and miniature reed relays for the interface elements. The delay circuits have been constructed using an RC integrator followed by a Schmitt Trigger. A Schmitt Trigger is simply constructed using one half of an integrated circuit quad inverter. The unit was built mainly for checking the logic operation and the noise immunity of the circuit. The noise immunity was checked in the laboratory using simulated noise.

Although resistor transistor (RT) integrated circuits were used for the model, diode transistor (DT) logic elements are recommended for better noise immunity.

It will be pointed out here that it is possible to realise a fully electronic unit using high-voltage medium-power transistors instead of the reed relays. However this results in a very complicated circuitry to control the line polarity returned on the incoming a, b wires.

ACKNOWLEDGEMENTS

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The author wishes to thank Professor C. H. Miller and Mr. P. Watt of the Department of Electrical Engineering, University of Tasmania, for their help and encouragement. In particular, the author wishes to thank Mr. G. L. Crew of the P.M.G. Research Laboratories, Melbourne who suggested the project and read the manuscript of this paper.

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TECHNICAL NEWS ITEM

NEW A.P.O SWITCHING CENTRE FOR OPERATOR CONNECTED TRUNK CALLS

On 17th June the installing contractor, L. M. Ericsson, handed over to the Australian Post Office (A.P.O.) the Wangaratta Manual Assistance Centre for pre-commissioning tests. This manual assistance centre consists of a new design of operating position which is integrated with the A.P.O. standard automatic trunk switching equipment, the ARM exchange. The installation consists of 15 trunk assistance positions, four special service positions and three supervisory positions, costing $337,000 with all associated equipment. The commissioning of this manual exchange in September 1969, will bring to fruition a project which started five years ago when work commenced on a specification for the manual assistance equipment.

Although the A.P.O. objective is to divert more and more telephone trunk traffic to direct dialling, i.e., subscriber trunk dialled (S.T.D.) operation, it is still necessary to invest considerable resources in the provision of manual switching equipment. Certain classes of trunk calls such as particular person calls, fixed time, reverse charge, and overseas calls cannot be directly dialled by subscribers. Over the next six years about 300 operating positions of the new design will be installed at 20 manual assistance centres throughout Australia to handle this non-S.T.D. component of trunk traffic.

Equipment has also been ordered for Newcastle (43 trunk assistance positions, 30 special service positions and 11 supervisory positions) and work at this centre is currently proceeding. An additional feature of this installation which has not yet been included at Wangaratta is a queueing facility which ensures that all calls are answered by the operators strictly in their order of arrival. The special queueing equipment also displays to the operator information regarding the origin and category of the incoming call, and arranges for emergency calls to go immediately to the head of the queue. These and other special features of the new cordless manual assistance centres are designed to give more efficient handling of operator connected trunk calls.

The electrical design of the switchboard was carried out by L. M. Ericsson in Sweden and is a substantial adaption of their basic manual switching system design. The operating console was produced by the North Electric Company of the U.S.A., and that Company adapted their standard console to satisfy the A.P.O. operating requirements and the circuit design produced by L. M. Ericsson. The development has included not only the main trunk assistance position but also ancillary special service and supervisory positions necessary for a manual switching centre. The physical characteristics of all the positions have been based on the one North Electric Company model.

Following visits by A.P.O. engineers to Sweden and U.S.A. late in 1967, the equipment production and installation has run to a tight and closely coordinated schedule. This new type of switchboard will be used extensively throughout the Australian network in the future for connecting both national and international calls.

TRANSISTORISED POWERLINE CARRIER EQUIPMENT

J. W. WARTH *

INTRODUCTION

To provide some of the trunk line services for its own internal communications system (Ref. 1), the Electricity Commission of N.S.W. uses various types of powerline carrier equipment. This article describes a recent type supplied to the Commission.

GENERAL

As its name suggests, the equipment operates through a special coupling circuit over the high tension powerlines themselves, allowing the provision of telephone communication wherever high tension power lines exist. A brief description of one type of coupling equipment is given at the end of this article.

The system provides a single 4 kHz channel which is subdivided to provide the following: a speech channel from 0 to 2.4 kHz; a frequency shift signalling channel at 2.55 kHz and 2.61 kHz; and up to eight frequency shift telegraph channels from 2.82 kHz to 3.66 kHz. Fig. 1 is block diagram of a complete terminal, while Fig. 2 shows how the system frequencies are used.

The 4 kHz baseband is modulated twice and then transmitted to line in one of two bands, 152 - 200 kHz or 406 - 480 kHz. The first modulation stage is the result of modulating a crystal controlled 15 kHz source and selecting the upper sideband product. This intermediate frequency then modulates the high frequency source for transmission to line.

Generally, standard carrier principles are followed, varying only in detail to suit the approach of the designer, and the requirements of the Electricity Commission.

CONSTRUCTION

The equipment is mounted on one side of a pressed steel rack, approximately nine feet high and twenty one inches wide. Plug-in units are employed throughout, the smaller units clipping in by special locking devices, while the larger units are secured by screws. Printed circuit boards are used with components mounted on one side of the board only. Removable dust covers are fitted to bollards at the rear of the rack, whilst hinged doors cover the front except for the test and monitor panels, located in the centre front.

For unit servicing and setting up adjustments, an extension plug-in frame is used, which is fitted with circuit isolating plugs. Special tools are provided for releasing the lock-in clips, and they double as handles when extracting the units from the shelves.

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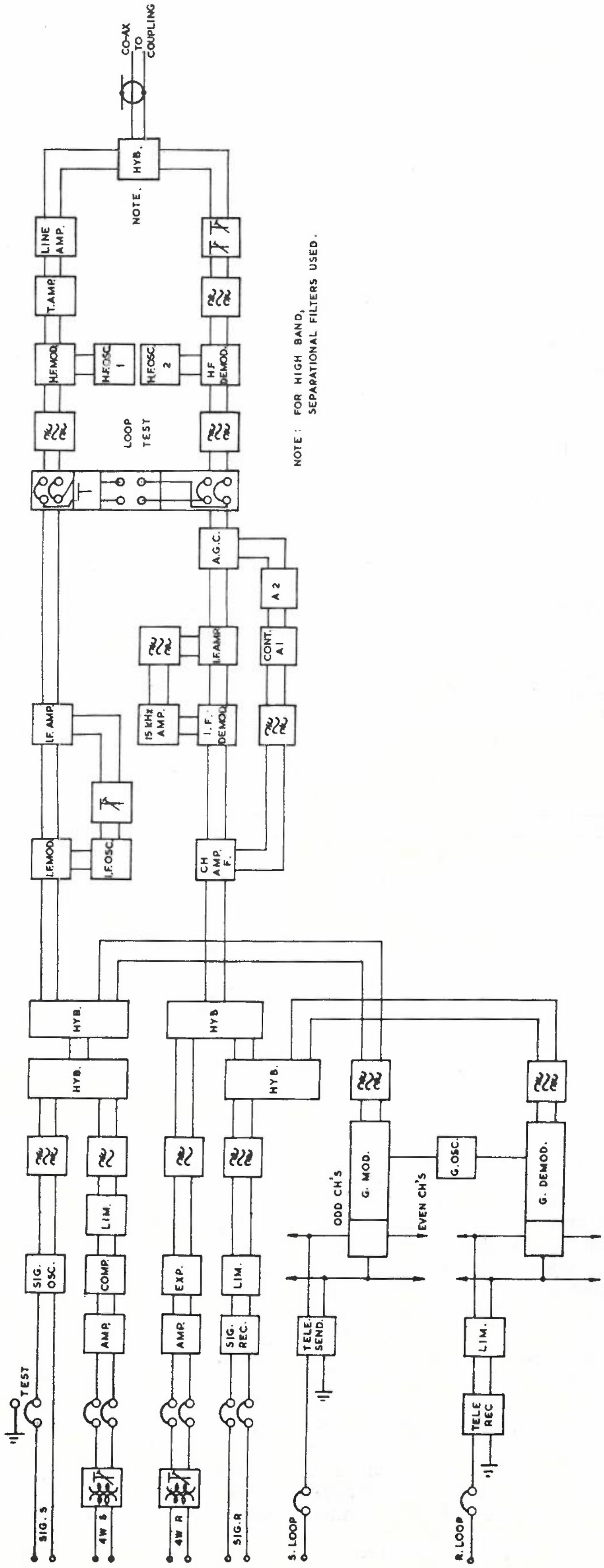

Fig. 1 — Block Diagram of Terminal.

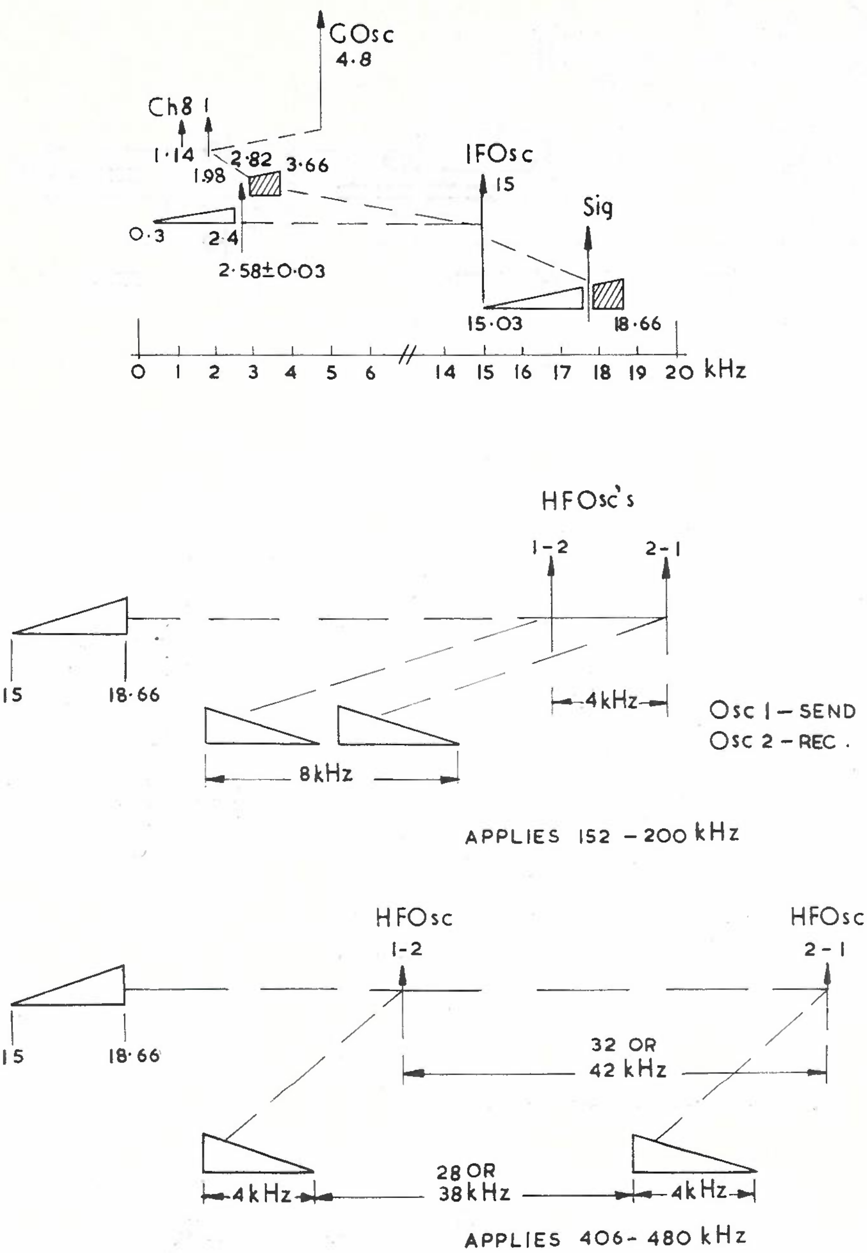

Fig. 2 — Frequency Allocation.

All the necessary tools and test plugs are provided with each rack, together with a set of handbooks and circuits.

The test and monitor panels allow for the complete testing of the terminal without the need for any other test apparatus. It includes impulse generators for testing the signalling and telegraph channels, as well as level meters and current and voltage test meters.

POWER SUPPLIES

The equipment has been designed to operate from a nominal 50 volt battery. The primary d.c. is fed into a voltage regulator panel which caters for input variations from 43 to 65 volts, maintaining the output from 43 to 53 volts.

A contact making voltmeter is connected across the output, with its contacts set at 43 and 53 volts. If the voltage falls to 43 volts, a bank of diodes is switched out to increase the volts by 6 to 8. If on the other hand the voltage rises to 53 volts, the diodes are switched in to drop the volts by the same amount. Should the voltage fall to 30 volts, a fail safe relay releases, disconnecting the input and initiating an urgent alarm.

The output of the d.c. regulator is fed to a static inverter unit which generates a 200 volt 200 Hz output, substantially constant for input variations between 43 and 53 volts.

This 200 Hz voltage is finally fed into a power pack which provides the various voltages used, e.g. —21 volts, —24 volts, —50 and +50 volts.

An external 50—0—50 volt telegraph battery is used for the telegraph channels.

THE A.G.C. SYSTEM

To maintain receive signals more or less constant with varying line attenuation, an automatic gain control system is employed. It will cater for line variations of + or —25 dB before it fails, and for variations up to + or —15 dB, will maintain the output within + or —0.5dB of normal.

The 15 — 19 kHz intermediate frequency signal is fed into the A.G.C. amplifier. In the output of the amplifier is a TT pad network, part of which consists of two indirectly heated thermistors.

The signalling channel frequencies are used as the pilot signal and are fed into the two controlling amplifiers, Cont. A1 and Cont. A2 in Figs. 3 & 4.

Cont. A1 is a three stage amplifier whose gain is set by altering the feedback resistors R22-R27. The output is rectified and fed into the second controlling amplifier, Cont. A2. This is a two stage d.c. amplifier, whose input voltage is compared with a standard voltage set by a zener diode and the resistor network R6—R10. Any difference between the applied and the standard voltage appears at the base of the first transistor and is amplified. The heating elements of the two thermistors in the A.G.C. amplifier output pad form the load of the second transistor.

Cont. A2 also incorporates the A.G.C. fail alarm. Under normal operating conditions, the second zener diode and its associated network, maintain the current in the meter relay MRL so that it is in a central position. Should the receive signal vary by more than 25 dB, contacts in MRL will close causing relay R1 to operate. Relay R1 operating, changes the load of TS2 to a fixed resistor, and replaces the load current through the thermistors with a predetermined, fixed current. It also initiates an A.G.C. fail alarm.

THE COMPANDER

To cater for a wide range of input speech levels, and yet maintain a good signal to noise ratio, a compander system is employed.

At the transmitting end, speech signals are fed into a compressor, which compresses the signals in the ratio of 1 to 2

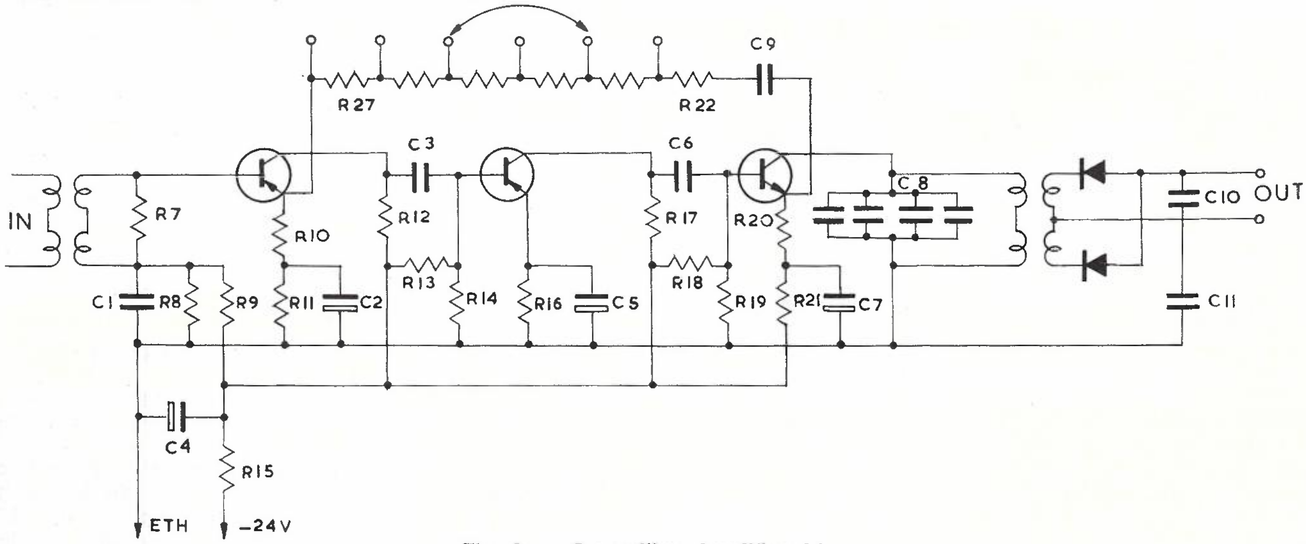

Fig. 3 — Controlling Amplifier A1.

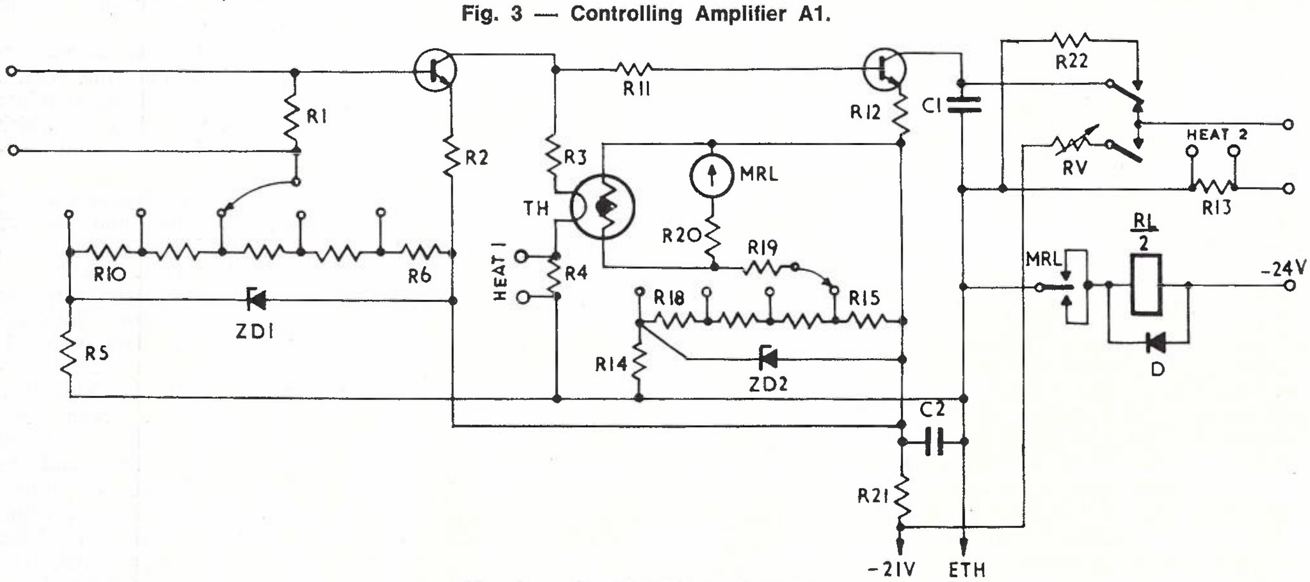

Fig. 4 — Controlling Amplifier A2.

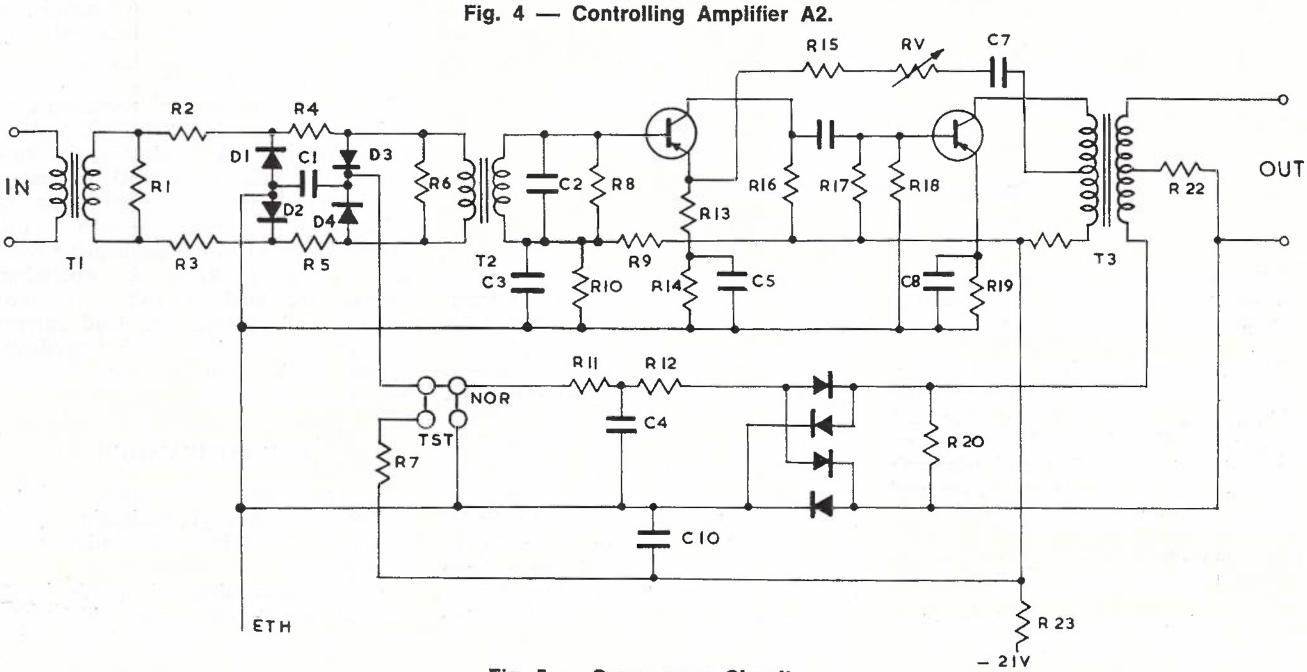

Fig. 5 — Compressor Circuit.

TABLE 1: COMPANDER CHARACTERISTICS

Compressor		Expander	
Input (dBm)	**Output (dBm)**	**Input (dBm)**	**Output (dBm)**
—50	—29	—21	—42
—46	—27	—20	—40
—36	—22	—15	—30
—26	—17	—10	—20
—16	—12	—5	—10
—8	—8		
—6	—7	0	0
—4.5	—6.25	+1.75	+3.5

around a given mean. (See Table 1). At the receiving end the process is reversed and the signals expanded in the ratio of 2 to 1. Where two terminals are connected back to back for long hauls, the compander may be switched out at the back to back location. Fig. 5 is the circuit of the compressor.

THE 15 kHz INTERMEDIATE FREQUENCY

The first stage modulation is the result of modulating the output of a 15 kHz crystal controlled oscillator. The output of the oscillator is also fed directly to the second modulation stage. At the receiving end, this 15 kHz signal is extracted by means of a very narrow bandpass filter (30 Hz) and after amplification is used as the demodulator oscillator source. This is done to maintain transmit and receive signals in synchronism. Use is made of this common transmit and receive frequency in the 'Loop Test' feature, whereby send and receive paths may be tested locally. The 15 kHz frequency is common to all Fujitsu systems supplied to the Commission.

THE SIGNALLING CHANNEL

A frequency shift channel outside the normal speech band is used for signalling over the carrier. Keying is accomplished by biasing a diode switch, to switch in or out of circuit additional L.C. components in the oscillator tank circuit. The signalling frequencies are also used as the A.G.C. pilot signal, described earlier.

TELEGRAPH CHANNELS

The racks may be fitted with up to eight bothway telegraph channels. They use the same frequency shift method of keying as the signalling channel. The eight channel oscillators are in the 1.14 to 1.98 kHz band and are group modulated up to 2.88 to 3.66 kHz by a 4.8 kHz signal. This has been done so that the telegraph channels may be used without group modulation over other speech-band paths.

Telegraph channels are used for telemetering, remote supervisory control and alarms.

LINE AMPLIFIER

To maintain a good signal-to-noise ratio and to allow for losses which may be present or occur, powerline carriers incorporate a high level transmitting amplifier. The Fujitsu amplifier has a power rating of 10 watts and the transmit level for speech is +33 dBm. Heavy negative feedback is used and the amplifier exhibits a substantially flat response over its entire range. The out-

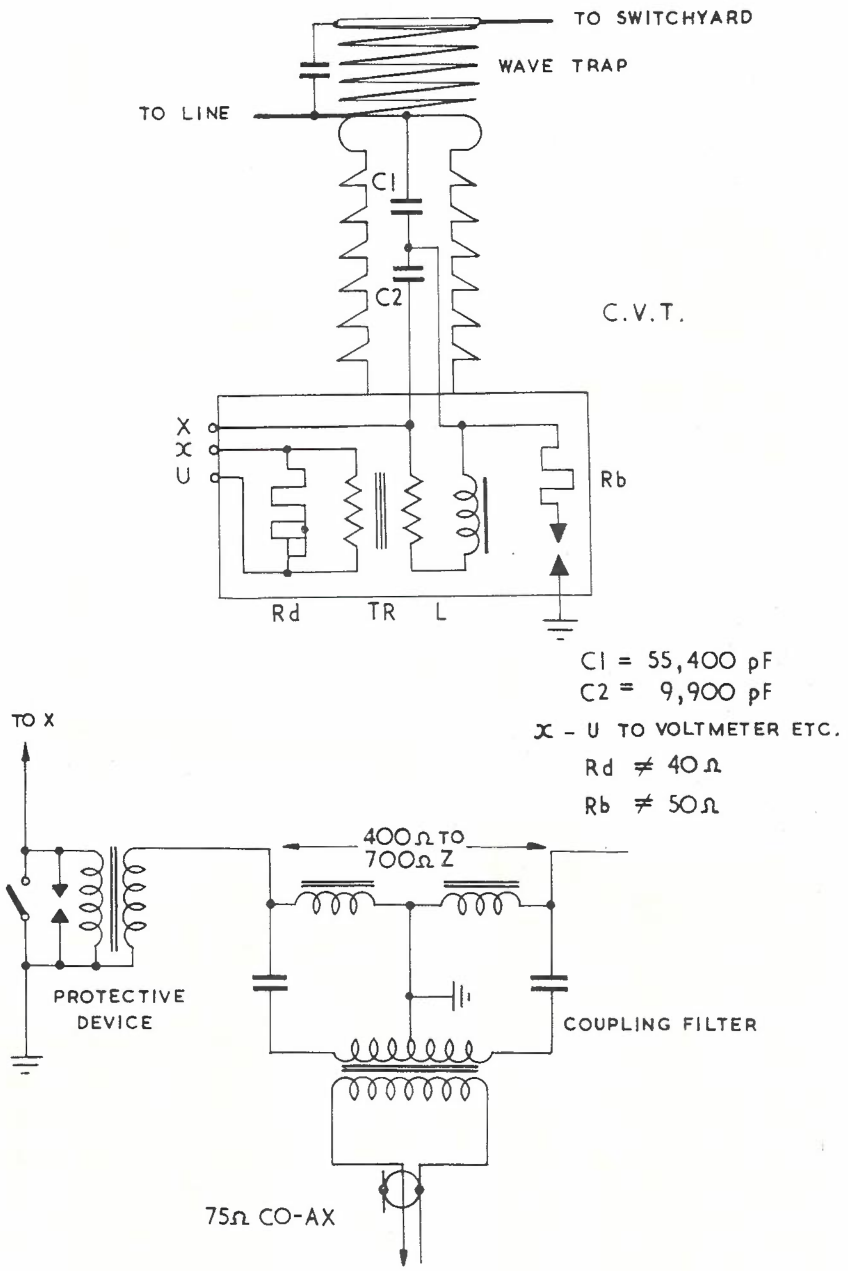

Fig. 6 — Coupling Unit.

put is monitored by means of a contact making meter-relay, which alarms if the output varies by more than a preset amount. A level meter is also connected to the output so that the transmit level may be read at all times. This meter is mounted on the monitor and test panel.

COUPLING EQUIPMENT

The coupling equipment (Fig. 6) allows the carrier signals to be coupled to the high tension feeder itself, without the high tension voltage being connected to the carrier equipment.

The actual coupling unit is a high voltage capacitor, the carrier being coupled to two of the three phases of the three phase line. Wavetraps are connected between the line and the switchyard to isolate the switchyard and its heavy losses from the carrier signals. The point at which the carrier signal is connected is maintained at virtually earth potential to the 50 Hz mains potential by means of drain coils or transformers. Protective devices and arc gaps are fitted for breakdown protection.

The capacitor is customarily made up of a number of units connected in series, each unit being rated at approx. 8 kV. The total capacitance of a typical unit is about 8,200 picofarads.

Coupling capacitors are also used as voltage sources for feeder protection and metering.

The carrier output is fed via a coaxial cable from the rack to the switchyard, where it is connected to matching transformers, protective devices and the coupling capacitors. Line impedances are in the order of 400 to 700 ohms, with attenuation at carrier frequencies of about 30 dB per 100 miles.

CONCLUSION

Powerline carriers are a logical method of providing internal communications for undertakings such as those of the New South Wales Electricity Commission.

The main disadvantage is that services may be lost during feeder outages, planned or unplanned. During times of storms and rain, where high leakage currents may occur, some systems become fairly noisy, but this has to be accepted to gain the economy of not providing separate bearers for communication channels. Apart from this, they generally provide good, reliable communication.

ACKNOWLEDGMENT

Permission of the Electricity Commission of N.S.W. to publish this article, is acknowledged.

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TECHNICAL NEWS ITEM

TELECOMMUNICATIONS FOR EDUCATION

The Australian Post Office has been interested for some time in the way telecommunications could assist in education and a seminar on 'Telecommunications for Education' was organised by the Department in May 1969. The aims were to inform educationists about telecommunication facilities available now and likely to be available in the future and to determine the needs for these in education.

A wide representation from Universities, tertiary and secondary colleges, the Victorian Education Department and some Commonwealth Government Departments attended.

Telecommunication aids to education were discussed under the general categories:—

(a) Audio-visual education.

(b) The application of computers for educational and administrative purposes.

Representatives of the educational institutions presented papers on existing and future developments in education which could use telecommunication facilities.

The discussion covered such development as the use of closed circuit television, which could have wide application in education and in-service training of teachers. Another and perhaps alternative service would be a telelecture network, requiring only standard voice lines and using audio associated with facsimile transmission. This "blackboard by wire" facility would be considerably cheaper than closed circuit T.V. and still satisfy many needs.

The seminar resolved that the Australian Council for Educational Research be invited to form a Working Party to report on the likely level and location of special education facilities which will require telecommunications. This report could then form the basis of cost and feasibility studies by the Australian Post Office.

MATHEMATICS OF RELIABILITY

. . *G. P. KIDD, B.E., B.Sc.**

INTRODUCTION

Engineers have always understood intuitively the concept of reliability: factors of safety are their means of ensuring a long system working life with only a small risk of failure. But these factors are often quite arbitrary—and usually unnecessarily conservative—because the ranges of component variation are unknown or, if known, the manner in which such variations interact when components are assembled into a unit is uncertain.

In recent years the rule-of-thumb approach to design has become less and less acceptable. The need for equipment to meet a specified reliability, stimulated particularly by the requirement that complex aviation, military and space systems should have a high probability of successful operation during a defined critical period (hence the emphasis in much reliability literature on 'mission availability'), coupled with the need to conserve an already limited maintenance manpower, has demanded a more quantitative approach to design. The awareness of this has led to the development of a satisfactory (but by no means final) mathematical theory of reliability.

This paper will present and discuss some of those aspects of the theory which are considered to be most useful in the telecommunications field.

RELIABILITY

To formalise the concept of reliability the following definition is given (Ref. 6):

> The reliability of a system or device is the probability that it will operate within defined limits for a specified time under specified environmental conditions.

One interpretation of this definition in the telecommunications context is that equipment should perform within specification for a sufficient period; another, is that there is only a small chance that grade of service would suffer or that maintenance facilities would be over-strained.

BASIC CONCEPTS

Failure Density Function, f(t)

Consider a number N of similar systems or components operating under identical conditions over a very long period. After some interval, t, from the beginning of operation (or, if repair is possible, from the previous repair instant) an item will fail or will otherwise drift outside its specified operating range. Over the whole period of observation suppose n failures occur. (If there is no repair, and all items fail, then n = N.) Assume also that the time intervals to failure are recorded in discrete steps of 2h, the i-th interval being $t_i \pm h$.

Now of the total of n failures, n_1 of them will have failure times falling in the first interval, n_2 in the second, n_i in the i-th, and so on. If the values of n_i are normalized by dividing through by n and the resulting ratios n_i/n plotted against time-to-failure t_i, then the resulting histogram represents the *time-to-failure density function* of the items. The area under the histogram is unity and so it has the characteristics of a probability density function thereby allowing probabilistic statements about failure to be made.

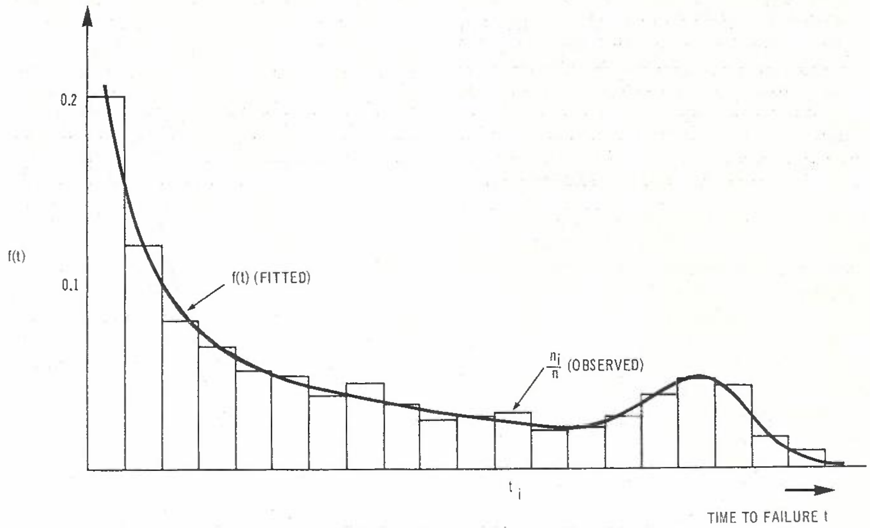

Fig. 1 — Failure Density Function f(t)

The normalized histogram could take any form, but for reasons given later it is assumed to have the particular form shown in Fig. 1. In that figure a continuous failure density f(t) has been drawn to approximate the discrete density. From this curve the probability p_{ij} of an item failing in the interval t_i to t_j is given by the area bounded by the ordinates at these points and the curve.

Failure Distribution Function, F(t)

The failure distribution function is defined for continuous f(t) as

$$F(t) = \int_0^t f(s)\, ds,$$

or for discrete densities

$$\Pr(t_i) = \sum_0^i p_j,$$

where p_j is the probability of failure in the j-th time interval ($p_j = n_j/n$). The failure distribution function gives the probability that an item will fail in the interval [0, t] or [0, t_i].

Failure-rate Function, r(t)

The failure-rate function, r(t) (sometimes designated as $\lambda(t)$ or z(t)), is defined as the ratio of the probability that failure occurs in an interval given that it has not occurred prior to t (the start of the interval) to the interval length (Ref. 2).

The failure rate in a given interval is given simply as

$$r \simeq \frac{\text{number of failures in the interval}}{\text{number of units operating at beginning of interval}}.$$

From the data in Fig. 1 the various values of r_i can be plotted against the time-to-failure t_i. The resulting shape of this graph depends on the form of the density function and for an arbitrary density function could take any form. For the particular density function of Fig. 1 the corresponding failure-rate function would take the form shown in Fig. 2. A continuous function r(t) has been drawn, as in Fig. 1, to approximate the discrete function.

The *instantaneous failure-rate* (sometimes called the hazard rate) is the limit of r(t) as the interval length tends to zero. This instantaneous failure-rate function gives the probability that an item that has been operating successfully for a period t will fail in the next instant of time.

The probability therefore that an item will fail in the interval [t, t + dt] given that it is operating at instant t is

$$r(t)\, dt.$$

Note that this is the *conditional* probability of failure in this interval; the *unconditional* probability of failure in the same interval is

$$f(t)\, dt.$$

Essentially the difference between these two is that for the first the item's behaviour is unknown only beyond the instant t (its characteristics being completely determined before this instant), whereas for the second the behaviour is unknown throughout the whole interval [0, t] and beyond. An analogy can be drawn from actuarial statistics: a child at birth has a small chance of dying between (say) 95 and 100, while a person actually surviving to 95 has a considerable chance of dying before he is 100.

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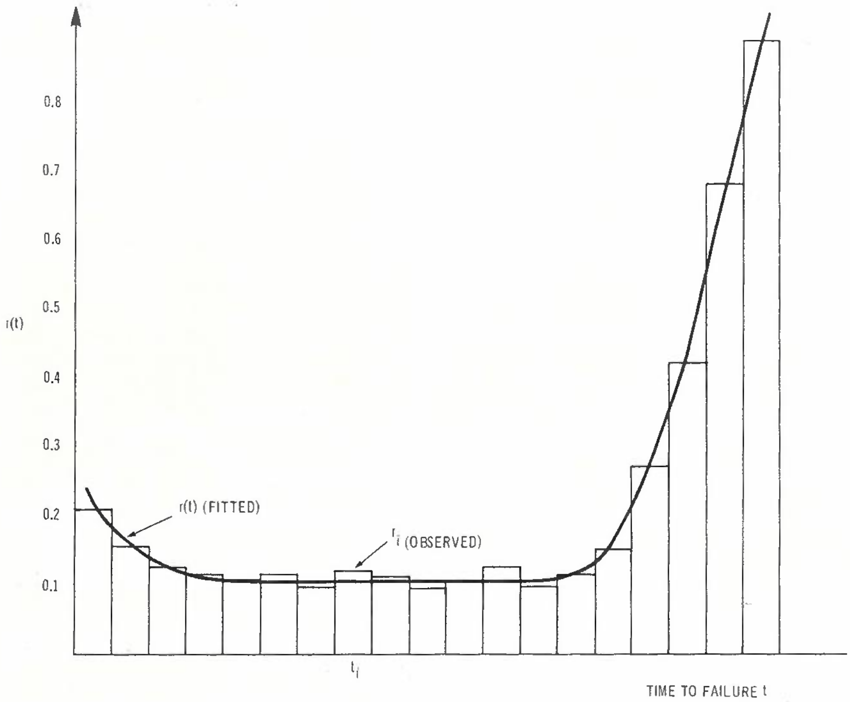

Fig. 2 — Failure-Rate Function r(t)

Reliability Function, R(t)

The reliability function (sometimes called the survival function) is defined as

$$R(t) = 1 - F(t),$$

where F(t) is defined above and represents the probability of failure in the interval [0, t]; R(t) is the probability that the item will *not* fail in this interval and therefore expresses the probability of survival to the instant t. This function is shown in Fig. 3 for the particular failure density function of Fig. 1.

It can be shown (see Appendix I) that f(t), r(t) and R(t) are linked by the relationship

$$r(t) = \frac{f(t)}{R(t)}.$$

Mean Life

A useful parameter in defining the time-to-failure density function is the mean life θ. For non-repairable items this is equivalent to the mean (or expected) time-to-failure (MTTF), and for repairable items it is equivalent to the mean (or expected) time-between-failures (MTBF). Its inverse gives the expected number of failures per unit time. (It should be noted that this is not the only parameter that could be used, nor does it, in general, completely define the density function (higher-order moments such as variance would also be needed for this).)

For continuous density functions the mean life is defined as

$$\theta = \int_0^\infty t\, f(t)\, dt.$$

This can be shown (see Appendix II) to be identical to

$$\theta = \int_0^\infty R(t)\, dt,$$

if the failure-rate r(t) does not tend to zero as t tends to infinity. For discrete functions summation replaces integration thus:

$$\theta = \sum_i t_i p_i$$

or

$$\theta = \sum_i R_i,$$

where p_i is the probability of failure in the i-th interval and R_i is the reliability function at the i-th interval.

Renewal-rate, ν(t)

In the discussion above on failure-rate r(t), it has been implicitly assumed that the number of remaining items at a particular instant decreases with time; that is, it has been assumed that there has been no repair or replacement of failed items. However there are many situations (and most of those encountered in telecommunications systems fall into this category) where renewal of failed items takes place more or less instantly so that the number of remaining items at any instant remains sensibly constant. Such a system operates in principle for ever.

The renewal-rate, $\nu(t)$, is expressed in an analogous way to failure-rate as the ratio of the number of failures in an interval [t, t + dt] to the number of operating units at the commencement of the interval. That is,

$$\nu(t)\, dt = \frac{n(t + dt) - n(t)}{N}$$

is the probability that a renewal will take place in [t, t + dt] where N is the total number of units put into service at t = 0, and n(t) is the number of failures up to time t. On the other hand

$$r(t)\, dt = \frac{n(t + dt) - n(t)}{N - n(t)}$$

Note that, numerically, the number of failures n(t) is not the same in both formulas since one includes failures of renewed items and the other does not.

By integrating $\nu(t)$ between 0 and t it can be found that

$$\int_0^t \nu(u)\, du = \bar{n}(t) = n(t)/N,$$

where $\bar{n}(t)$ is the mean number of renewals in the interval [0, t], and is called the renewal function. It follows that its derivative is the renewal rate.

It can be demonstrated (Ref. 7) that if a system made up of a large number N of similar units operates for a sufficiently long time, with individual units being renewed upon failure, then the limiting value of the renewal-rate *for a unit* is given by

$$\lim_{t \to \infty} \nu(t) = \frac{1}{\theta_0}$$

where θ_0 is the MTTF of a unit. This limiting renewal-rate is independent of the under-lying failure density of the unit. That is, the renewal-rate of a unit after a large number of renewals tends to a con-

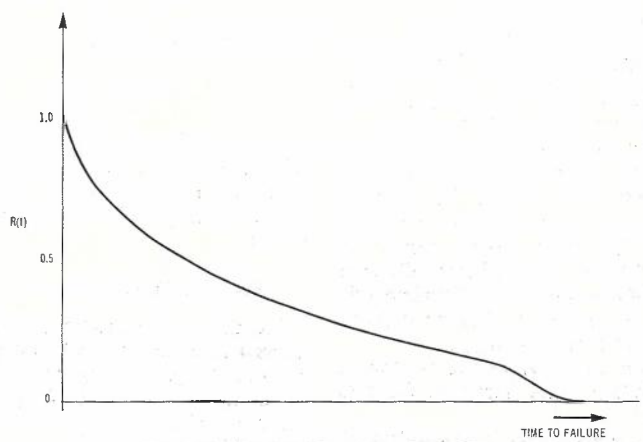

Fig. 3 — Reliability Function R(t)

tant, indicating that the limiting failure density is exponential (see below).

For a system made up of a certain number of units, each essential to its operation, system failure will occur whenever a unit fails. But since failed units are renewed, the system will also be renewed simultaneously, and will consequently have its own renewal-rate. In the limit (after a considerable number of renewals) this renewal-rate will be $\frac{1}{\theta_T}$, where θ_T is the mean-time-between-failures of the system and is the mean time between failure of a component and the next failure of any of the components. But from another point of view this system can be considered to be made up of series elements (see below) each with a constant renewal- (or failure) rate, so that the system renewal-rate is the sum of the individual element renewal-rates. It follows then that

$$\frac{1}{\theta_T} = \sum_i \frac{1}{\theta_i},$$

where θ_i is the MTTF of the i-th element. If there are m identical elements with $\theta_i = \theta_0$ for all i, then

$$\theta_T = \theta_0/m.$$

In the development of the above, the system under consideration has been assumed to be under control and to have been operating for a sufficiently long time to justify the assumptions made. Under these conditions the average number of failures, $\bar{n}(t)$, will increase linearly (subject to random fluctuations), so that its derivative the renewal-rate, will have zero-slope. If, however, the θ_0 of the individuals should change for the worse, indicating the approach of the end of useful life of repaired units, then $\bar{n}(t)$ will increase at a faster rate with a consequent upward trend of $v(t)$. As long as other parameters remain unchanged (particularly maintenance procedures) the slope of the renewal-rate function can be used therefore as an indicator of system stability.

Note that the time-scale used in plotting renewal-rate is a chronological one (months of the year for example), whereas for the failure-rate function it is an interval representing time-to-failure. If statistics were able to be collected on the individual element times-to-failure in a renewable system then renewal-rates could be presented in the same way as failure-rates, and a more thorough knowledge of the system would be obtained.

Discussion of Failure Modes

The failure density function can in theory (and often in practice) take any form. It has been found though that many components and systems used in electronics and communications have a density similar to that illustrated in Fig. 1. The corresponding failure-rate function (Fig. 2) has regions of decreasing, constant and increasing value which can be considered as representing burn-in, random failure and wear-out phases respectively. This type of model is certainly intuitively acceptable for mechanical components such as step-by-step switches, and would, though with probably less physical basis, appear to give a reasonable description of electronic component behaviour.

Mathematically this model requires three terms to describe each of the three phases of failure, viz:

$$f(t) = f_D(t) + f_C(t) + f_I(t).$$

In practice such a function would be very difficult to fit to a given set of failure statistics so some compromise is necessary. The most common simplifications are firstly to assume that the component or equipment is put into service only after the burn-in period, thereby allowing the first (decreasing failure-rate) phase to be ignored, and secondly, to assume that replacement or maintenance takes place before the third (increasing failure-rate) phase is reached. Of these assumptions the first is the least acceptable; the second can, at least in principle, be met by a controlled maintenance programme.

THEORETICAL FAILURE DISTRIBUTIONS

A particular set of failure data may be able to be approximated by more than one theoretical distribution function with more or less precision, but it is usual to restrict such distributions to one from a few of the better known and more mathematically manageable distributions. Some of these are given below with brief descriptions of their properties. Full discussions can be found for example in Refs. 1, 2 and 7.

Exponential Distribution

One of the most commonly used density functions is the exponential defined by

$$f(t) = \lambda \exp(-\lambda t),$$
$$0 \leqslant t < \infty, \lambda > 0.$$

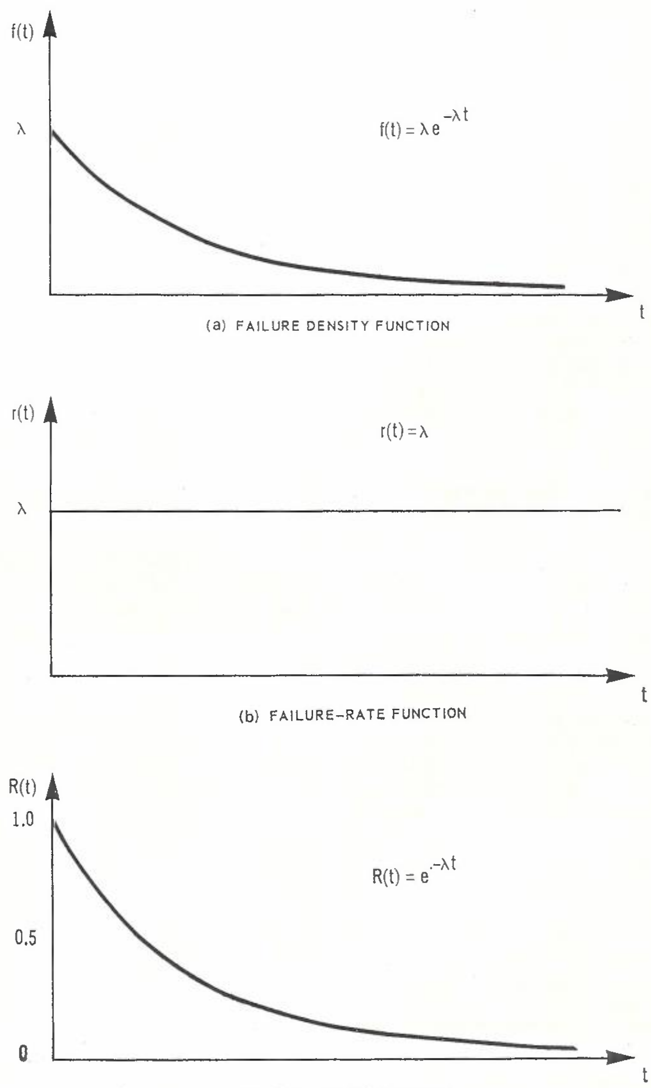

Fig. 4 — Exponential Distribution

The failure rate for this distribution is

$$r(t) = \lambda,$$

and the reliability function is

$$R(t) = \exp(-\lambda t).$$

These functions are shown in Fig. 4.
The mean life θ is given for this distribution as

$$\theta = \frac{1}{\lambda}.$$

The important characteristic of the exponential is its constant failure-rate λ, which makes it a suitable model for the second (constant-failure) phase of the assumed failure density of Fig. 2. However the exponential has a much more general applicability than this; namely it can be demonstrated (Ref. 1) that the exponential is the limiting failure distribution of a system made up of a very large number of single components operating over a long time. It is assumed that each component causes failure and that each component is replaced immediately at failure.

Weibull Distribution

A two-parameter distribution known as the Weibull has assumed an important role in characterizing failure mechanisms. Its failure density is defined as

$$f(t) = \lambda\beta t^{\beta-1}\exp(-\lambda t^{\beta})$$
$$\lambda, \beta > 0; \; t \geqslant 0.$$

λ is known as the scaling parameter and β as the shaping parameter. Selection of different values for these parameters allows a wide range of density function shapes to be fitted. Thus when $\beta = 1$ the exponential results. When $\beta < 1$ the density curve is more convex than the exponential, and for $\beta > 1$ it becomes humped. For β greater than about 3 the resulting curve tends to the Normal. These effects are illustrated in Fig. 5 (a) for $\beta = \frac{1}{2}$, 1.2, 2, and 4.
The failure-rate is found to be

$$r(t) = \lambda\beta t^{\beta-1}.$$

If $\beta < 1$ the failure-rate is decreasing (D.F.R.) and for $\beta > 1$ it is increasing (I.F.R.). Of course when $\beta = 1$ (exponential) it is constant. The failure-rates for various values of β are shown in Fig. 5 (b). The reliability function is given by

$$R(t) = \exp(-\lambda t^{\beta}).$$

Representative curves of this function are shown in Fig. 5 (c). For the Weibull distribution the mean life is

$$\theta = \left(\frac{1}{\lambda}\right)^{\frac{1}{\beta}} \frac{1}{\beta}\Gamma\left(\frac{1}{\beta}\right)$$

where $\Gamma(1/\beta)$ is the gamma function of $(1/\beta)$*. Note that *only if* $\beta = 1$ does the mean life θ equal $1/\lambda$.

For a given set of failure data it is necessary to estimate the two parameters β and λ. Sufficient accuracy is usually obtained in the estimation process by plotting the cumulative percentage of failure against time-to-failure on so-called Weibull probability graph paper. A complete description of how to use this probability paper to derive estimates of the parameters is given in Section 5.9 of Ref. 2. Note that a parameter α is used in that reference, where $\alpha = 1/\lambda$.

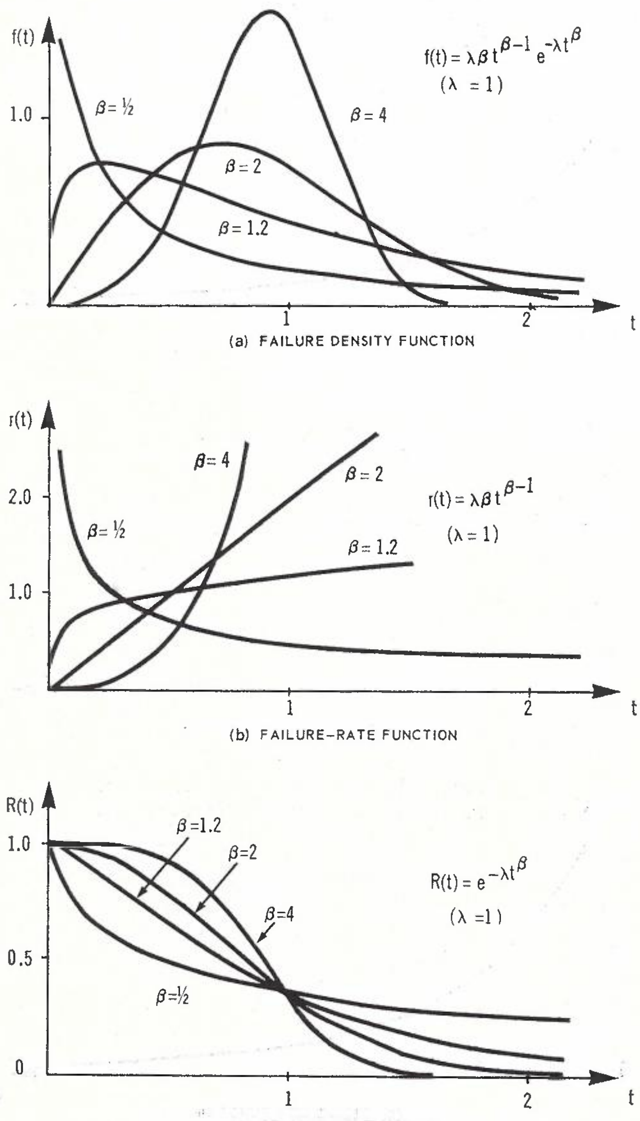

Fig. 5 — Weibull Distribution

Normal Distribution

The Normal is also a two-parameter distribution with density function defined by

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}}\exp - \frac{(t-\theta)^2}{2\sigma^2},$$
$$-\infty < t; \; \theta < \infty; \; \sigma > 0.$$

Note that the density is defined for $t < 0$ which of course is physically unrealizable. However if θ/σ is sufficiently large this is not a serious limitation.

The failure-rate function can be found from

$$r(t) = \frac{f(t)}{R(t)}$$

where R(t) the reliability function is given by

$$R(t) = \int_t^{\infty} f(s)\,ds$$

R(t) can be found from tables of the Normal distribution. Graphs of f(t), r(t) and R(t) are shown in Fig. 6. The mean life for this distribution is θ.

It would seem from physical considerations that the Normal has no distinct advantage over the more general Weibull distribution; however there is a considerable theory built up for the Normal which makes it more attractive from the mathematical point of view.

Poisson Distribution

The Poisson is a discrete distribution whose density function expresses the probability that there will be just x failures in a

* $\Gamma(x) = \int_0^{\infty} e^{-t}\,t^{x-1}\,dt$
Tables of this function can be found, for example, in Reference 10.

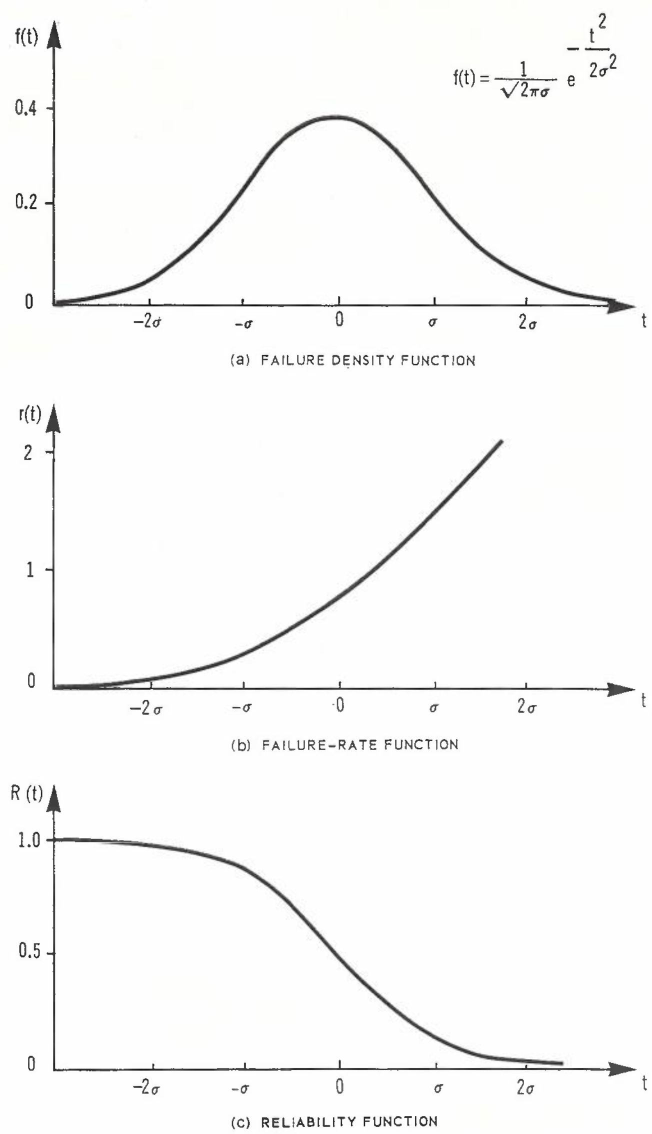

Fig. 6 — Normal Distribution

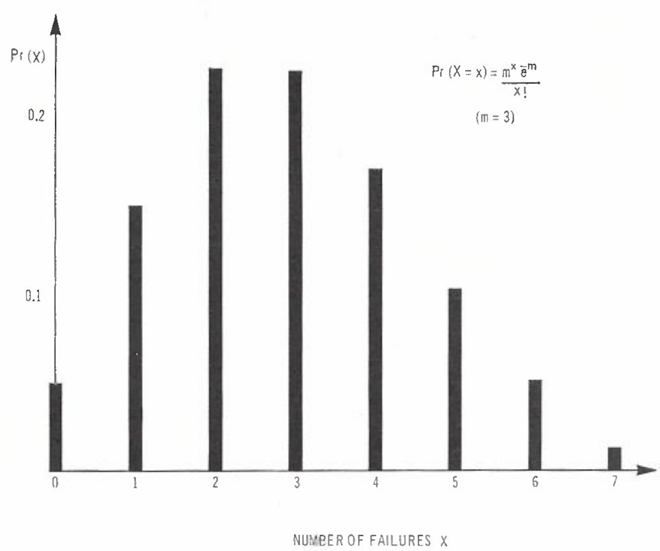

Fig. 7 — Poisson Distribution

given time interval. Its density function is defined by

$$Pr [X = x] = \frac{m^x e^{-m}}{x!},$$

where m is the expected number of failures in the time interval. Thus the probabilities of 0, 1, 2 . . . failures of the system during the interval 0 to t are given by

$$Pr [0] = e^{-m}$$

$$Pr [1] = me^{-m}$$

$$Pr [2] = \frac{m^2}{2} e^{-m} \quad \text{. . . etc.}$$

The function is plotted in Fig. 7 for a value of m = 3. When m is sufficiently large (m greater than about 5) the Poisson can be approximated by the Normal with mean m and standard deviation $\sqrt{m}$.

Pr [X = 0] gives the probability that there will be no failures in the interval [o,t] and therefore represents the reliability of the system.

i.e. $R(t) = e^{-m}$

Now if $m = \lambda t$ this reliability function is directly equivalent to that of the exponential distribution, where λ is the exponential failure-rate expressed as expected number of failures per unit time. It can be inferred then that if a system has an exponential time-to-failure distribution its number of failures per unit time will follow a Poisson law, and conversely.

Other Distributions

Some other distributions which have been considered in the literature include the gamma, log-normal, truncated normal, chi-squared and binomial. Discussions of their properties can be found for example in Refs. 1, 2, 3 and 5.

PREDICTION OF RELIABILITY

In the preceding section the emphasis was on characterising the reliability of *one* type of component or system. That is, it was an *a posteriori* problem: components or systems already existed to be tested. The *a priori* problem, that of *prediction* of reliability, will be considered in this section.

Basic configurations used in the analysis of reliability are shown in Fig. 8. Note particularly that the descriptors (viz. series, parallel, etc.) refer to the dependence of the units in a reliability sense and not necessarily in a circuit sense. Fig. 8 (a) is the common example of series dependency in which failure of one element results in failure of the system. Parallel dependency as indicated in Fig. 8 (b) allows (in the simplest case) the system to continue operating in the event of some of the units failing.

Parallel dependency is the basis of a powerful method of obtaining a system of specified reliability from generally less-reliable components by making use of redundancy of components or sub-systems. The principle of redundancy is that certain similar units are replicated in such a way that the system does not fail until all units have failed. If repair of a unit is possible, an even better reliability can be obtained.

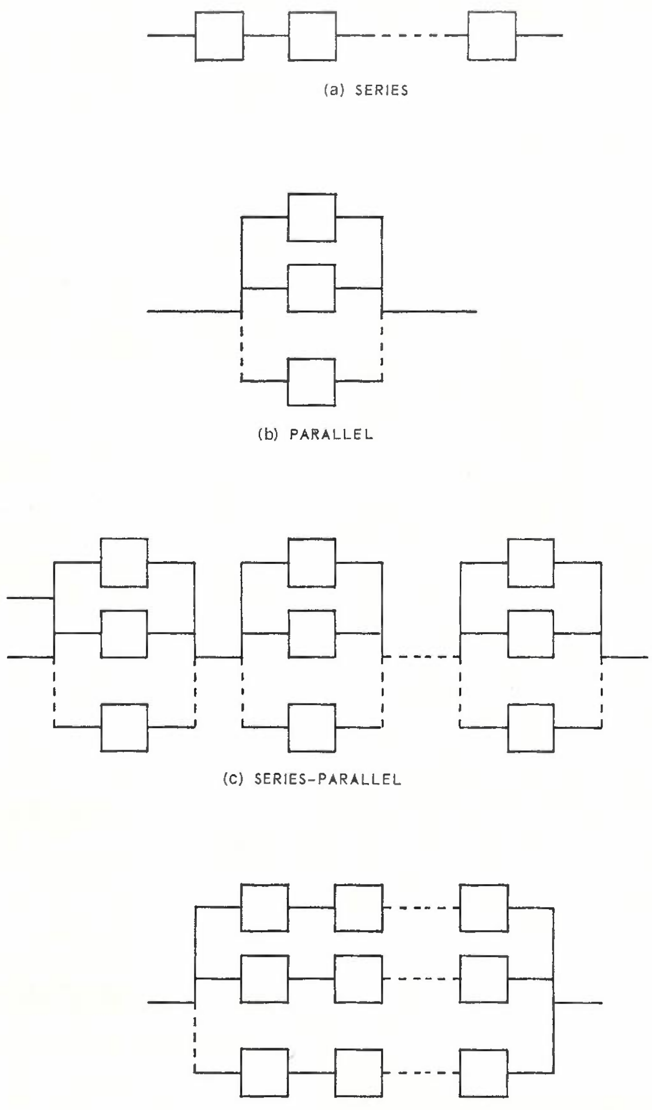

Fig. 8 — Basic Redundant Configurations

The characteristics of the various configurations are summarised below.

Series Configuration

For the series configuration of Fig. 8 (a) it is assumed that the failures of the individual elements are independent of one another and that system failure occurs if just one element fails. That is, at any instant of time, the system survives only if all elements survive to that time. Under the assumption of independence the probability of this combined event (survival of the system) is the product of the probabilities of the individual events (survival of the elements). In terms of reliability functions this can be expressed as

$$R_s(t) = \Pi_i R_i(t),$$

where $R_s(t)$ is the system reliability function and $R_i(t)$ the i-th element reliability function. It follows that $R_s(t)$ will always be less than the worst $R_i(t)$.

The mean-time-to-failure of this system is given by

$$\theta_s = \int_0^\infty R_s(t)\,dt.$$

As an example consider two series elements with Weibull failure distributions with common shape parameters β and scale parameters λ_1 and λ_2 respectively. The system reliability function is then

$$\begin{aligned} R_s(t) &= R_1(t)\,R_2(t) \\ &= \exp(-\lambda_1 t^\beta)\exp(-\lambda_2 t^\beta) \\ &= \exp -(\lambda_1 + \lambda_2)t^\beta. \end{aligned}$$

From this it can be inferred that the system failure distribution is Weibull with shape parameter β and scale parameter $(\lambda_1 + \lambda_2)$.

By putting $\beta = 1$ the case of two series exponential elements is obtained, and then

$$R_s(t) = \exp -(\lambda_1 + \lambda_2)t.$$

This result can be extended to any number, n, of series elements with exponential failure distributions. Therefore it follows that the failure-rate of a system composed of elements with constant failure-rates λ is given by

$$\lambda_s = \sum_i \lambda_i.$$

From the properties of the exponential the mean-time-between-failures of the system is

$$\theta_s = \frac{1}{\sum_i \lambda_i} = \frac{1}{\lambda_1 + \ldots + \lambda_n}$$

Note that this property is confined to series configurations of elements with exponential failure distributions.

Parallel Configuration

Consider m elements whose individual failures are independent of one another, integrated into a system in such a way that only when all elements fail does the system fail. Thus at any instant the probability of the system failing is the product of the probabilities that all of the elements will have failed by that time. These individual failure probabilities are given by

$$F_i(t) = 1 - R_i(t),$$

so that the system failure probability at instant t is

$$F_s(t) = \Pi_i F_i(t).$$

But the system reliability function is the probability of survival at instant t and is therefore given by

$$\begin{aligned} R_s(t) &= 1 - F_s(t) \\ &= 1 - \Pi_i F_i(t). \end{aligned}$$

If the elements are identical

$$R_s(t) = 1 - [F_i(t)]^m.$$

Again the system mean-time-between-failures can be found from

$$\theta_s = \int_0^\infty R_s(t)\,dt.$$

Consider a simple parallel system consisting of two elements with independent exponential failure distributions having parameters λ_1 and λ_2. The reliability functions for the two elements are therefore

$$R_1(t) = \exp(-\lambda_1 t)$$
$$R_2(t) = \exp(-\lambda_2 t)$$

It follows then that

$$\begin{aligned} R_s(t) &= 1 - F_1(t)\,F_2(t) \\ &= 1 - (1 - e^{-\lambda_1 t})(1 - e^{-\lambda_2 t}) \\ &= e^{-\lambda_1 t} + e^{-\lambda_2 t} - e^{-(\lambda_1 + \lambda_2)t}. \end{aligned}$$

Or, if $\lambda_1 = \lambda_2 = \lambda$,

$$R_s(t) = 2e^{-\lambda t} - e^{-2\lambda t}.$$

By integrating $R_s(t)$ over the range 0 to infinity the mean system life is found to be

$$\theta_s = \frac{1}{\lambda_1} + \frac{1}{\lambda_2} - \frac{1}{\lambda_1 + \lambda_2}.$$

Or, if $\lambda_1 = \lambda_2 = \lambda$,

$$\theta_s = \frac{3}{2\lambda} = \frac{3}{2}\theta,$$

where θ is the element mean life.

These results can be extended to the case of m parallel elements with constant failure-rates. In particular if all m elements have the same failure-rate λ the following results obtain:

$$R_s(t) = 1 - [1 - \exp(-\lambda t)]^m$$

$$\theta_s = \frac{1}{\lambda}\sum_i \frac{1}{i}.$$

It is to be noted that the system failure-rate is no longer the sum of the individual constant failure-rates as was the case for series elements.

These results form the basis of the theory of redundancy, in which units capable of performing the system function both independently and together, are operated in such a way as to lead to an increased mean life over that of any of the individual units. The duplicate parallel system of exponential elements considered above demonstrates the gains to be expected. These gains are not proportional to system complexity: doubling the number of basic units from one to two leads to only a fifty percent improvement in mean life, and percentage improvement decreases with further additional redundancy. However the real strength of redundancy is only realised when repair of failed units is possible; this situation will be discussed later.

Series-Parallel and Parallel-Series Configurations

The reliabilities of these configurations (Fig. 8 (c) and 8 (d)) can be calculated by first calculating the reliabilities of the individual blocks and then, by considering these as individual elements, the reliabilities of the overall system. Thus in the series-parallel case the reliabilities of each block of parallel units would be determined first using the formulas given above and these combined to give the reliability of the series of blocks. For the parallel-series case the series arms would be considered first.

As an example, suppose that it is required to calculate the reliability of two blocks of two parallel units, where all units have a constant failure-rate λ. The reliability of each parallel block is

$$R(t) = 1 - [F_1(t)]^2$$
$$= 2e^{-\lambda t} - e^{-2\lambda t}.$$

The reliability of the two identical series blocks is

$$R_s(t) = [R(t)]^2$$
$$= [2e^{-\lambda t} - e^{-2\lambda t}]^2.$$

By integrating $R_s(t)$ from 0 to ∞ the mean life can be found to be

$$\theta_s = \frac{11}{12\lambda} = \frac{11}{12}\theta.$$

On the other hand consider a parallel-series arrangement with two parallel arms each containing two elements in series, all elements again having constant failure-rate λ. The reliability of the individual arms is

$$R(t) = [R_1(t)]^2$$
$$= e^{-2\lambda t}.$$

The reliability of the system is

$$R_s(t) = 1 - [1 - R(t)]^2$$
$$= 2e^{-2\lambda t} - e^{-4\lambda t}.$$

The mean life for this system is then

$$\theta_s = \frac{3}{4\lambda} = \frac{3}{4}\theta.$$

These results can be extended to any number of units and blocks, and to cases where units have different failure-rates. In general the series-parallel arrangement has a better mean life than an equivalent parallel-series system, but for a particular design problem considerations such as whether a unit is likely to fail by short-circuit or open-circuit (or either) would control the configuration to be used.

REDUNDANCY

In this section the properties of parallel redundant systems will be considered in more detail. For simplicity the case of a system made up of only two parallel elements will be discussed, but the methods of analysis can be extended to a system consisting of m parallel elements.

In a duplicated redundant system the two elements can both be fully operational so that if one fails the other is immediately able to sustain the full load. This condition is called *active redundancy*. Alternatively, one element may be fully operational while the other is in reserve: when the first fails the second is switched into circuit and only then becomes fully operational. This is a condition of *standby redundancy*. A third possibility is that the two elements may each share the load with one taking the full load if the other fails. This condition of *partial-loading* includes the first two types of redundancy at one or other of its extremes.

For an active redundant system made up of identical elements having independent exponential failure distributions with mean life θ, the system mean life will be $\frac{3\theta}{2}$, as discussed in the preceding section. The system mean life for standby redundancy can be shown fairly simply to be 2θ, where identical elements having exponential failure distributions are assumed, and where the reserve element is not subject to failure. However for such a system the reliability of the switching process would have to be considered and the system mean life would then almost certainly be less than 2θ. If the reserve element is partly energized it will have some likelihood of failure (but of less intensity than when fully loaded) and the system mean life would again be less than 2θ.

The case of partial loading can be illustrated by considering a system of two parallel elements each with a mean life θ under half-load conditions and $\theta' = \theta/k$ ($k > 0$) under full-load conditions. The system mean life can be shown to be

$$\theta_s = \frac{\theta}{2} + \theta' = \frac{\theta}{2} + \frac{\theta}{k}.$$

When $k = 1$, $\theta' = \theta$ and the system is then equivalent to one using active redundancy as defined above.

Redundancy with Repair of Elements

Active and standby redundancy as discussed above are of limited interest in analysing the reliability of telecommunication equipment since such equipment is usually able to be repaired or replaced upon failure, and the above results are no longer directly applicable. (However they are valid for such items as submarine cable repeaters and satellite repeaters where repair is inconvenient or impossible.) The analysis needs therefore to be extended to include repair of elements.

Consider two elements in a parallel redundant configuration, where again it will be assumed that each element has a constant failure-rate λ. But now when either element fails it is repaired or replaced. The repair-time itself will be a random variable and will therefore have a particular density function which can be defined in the same way as the failure-time density function. The repair-time distribution could take any form but for convenience assume that it is exponential with parameter μ. That is the repair-rate (defined in the same way as the failure-rate) is constant and equal to μ. (More general failure- and repair-times are analysed in Ref. 9.)

For this condition of parallel redundancy the system will continue to operate as long as each failed element can be repaired before the remaining element fails. Failure of the system occurs only when the second element fails before repair of the first element is completed.

Epstein & Hosford (Ref. 8)* analyse both active and standby redundancy under the assumption of constant failure-rate λ and constant repair-rate μ. The mean life of an active redundant system with repair is found to be

$$\theta_A = \frac{3\lambda + \mu}{2\lambda^2}$$
$$= \theta_0\left(1 + \frac{\mu}{3\lambda}\right),$$

where θ_0 is the mean life of the active redundant system without repair. Similarly the mean life of a standby redundant system with repair is

$$\theta_S = \frac{2\lambda + \mu}{\lambda^2}$$
$$= \theta_0\left(1 + \frac{\mu}{2\lambda}\right),$$

where θ_0 is the mean life of the system without repair.

It is seen that considerable improvement in time-between-system-failure can be effected by repairing elements as they fail, since the mean repair-time should be substantially less than the mean failure-time and therefore μ should be much greater than λ.

* Reference 2 quotes Epstein & Hosford's results incorrectly: on p. 265 "Design A" should read "Design B" and vice versa. There is also an error in the formula for mean life for standby redundancy. With these corrections Fig. 8.10 is correct.

The analysis could in theory be extended to a system of m parallel elements of which k must operate successfully to maintain a specified system performance. An example of such a system would be a bank of exchange switches in which a certain number could be inoperative without lowering the grade-of-service to an unacceptable level. Rather than repair switches as they fail, groups of failed switches would be repaired at one time. (This, of course, is the philosophy of qualitative maintenance.) What needs to be defined for such a condition is the reliability function and hence the mean time to reach unacceptable performance. From these the probability of entering a region of degraded performance for a given maintenance effort could be determined.

CONCLUSION

This paper has presented a brief review of some reliability concepts and in doing so has ignored many aspects which are probably of equal importance. For example, in digital circuitry an effective method of improving reliability is to use parallel redundancy of logic units followed by a voting or decision stage: the majority vote determines the system state. Likewise no distinction has been made between life-testing and reliability-testing. In the one, components or systems are usually tested under conditions of high stress so that failures are induced in a shorter period than under actual conditions, while in the other, they are tested under normal operating conditions. The statistical methods of this paper are applicable to both, but in life-testing a knowledge of the physics of failure is also necessary to allow extrapolation of the results to actual conditions.

ACKNOWLEDGEMENT

The Author acknowledges a number of helpful discussions with Mr. George Moot during the writing of this paper.

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APPENDIX I

The failure-rate at instant t is given by the limit (as $\delta t \to 0$):

$$r(t) = \lim_{\delta t \to 0} \frac{R(t) - R(t + \delta t)}{\delta t \, . \, R(t)}$$

$$= -\frac{1}{R(t)} \cdot \frac{dR(t)}{dt}.$$

But
$$\frac{dR(t)}{dt} = \frac{d}{dt}[1 - F(t)]$$
$$= \frac{d}{dt}\left[1 - \int_0^t f(t)\,dt\right]$$
$$= -f(t).$$

Therefore

$$r(t) = \frac{f(t)}{R(t)}.$$

APPENDIX II

By definition

$$\theta = \int_0^\infty t\,f(t)\,dt$$
$$= \int_0^\infty t\,\frac{d}{dt}\,[-R(t)]\,dt.$$

Integration by parts gives

$$\theta = -tR(t)\Big|_0^\infty + \int_0^\infty R(t)\,dt.$$

At $t = 0$, $tR(t) = 0$ since $0 \leqslant R(t) \leqslant 1$ for all t.

For the upper limit $\lim \left[\frac{-t}{R(t)^{-1}}\right]$ is undefined. L'Hospital's rule though gives

$$\lim_{t\to\infty}\left[\frac{-t}{R(t)^{-1}}\right] = \lim_{t\to\infty}\left[\frac{-\frac{d}{dt}(t)}{\frac{d}{dt}\left(\frac{1}{R(t)}\right)}\right]$$
$$= \lim_{t\to\infty}\left[-1 \cdot \frac{R(t)^2}{r(t)R(t)}\right]$$
$$= \lim_{t\to\infty}\left[-\frac{R(t)}{r(t)}\right]$$
$$= 0,$$

if r(t) does not tend to 0 as t tends to infinity. Therefore

$$\theta = \int_0^\infty R(t)\,dt.$$

USE OF EXPLOSIVES NEAR COAXIAL CABLES

M. F. LETTE, A.S.T.C., M.I.E. Aust. *

INTRODUCTION

With the increasing use of coaxial cables, cases are arising where other Utilities, Authorities and private contractors seek advice on, or require to use explosives in the vicinity of coaxial cables.

This paper describes a field investigation on the use of explosives near a coaxial cable. Since coaxial cables are by their construction less robust and more liable to damage than conventional cable, it follows that the conclusions at the end of this paper could be applied to conventional cables.

DAMAGE CRITERION

When this problem was first investigated it was thought that amplitude and frequency of vibration, recorded by the Cambridge Vibrograph up to the failure of any tube would be a satisfactory damage criterion.

However recent developments overseas have indicated that this instrument cannot record the high frequencies (from the Civil Engineer's viewpoint), in the order of 100-1000 c.p.s. found in close proximity to a blast, and the modern technique is to use geophones coupled with oscilloscopes. As the shock waves pass through the ground the geophones record the velocity of the ground movement (hereafter called particle velocity), and by using this arrangement the threshold for particle velocity could be determined below which cables would not be damaged.

The N.S.W. Department of Mines agreed to supply their equipment for the test and it consisted of the following:

(i) One vertical recording geophone
(ii) One horizontal (longitudinal) recording geophone
(iii) One horizontal (transverse) recording geophone
(iv) Four (4) channel oscilloscope equipped with a polaroid camera to record all results.

Figs. 1 and 2 show the above equipment.

TEST PROCEDURE

All formulae used in determining the possible damage effect of explosives on structures are empirical. Consequently the only way to achieve results for coaxial cable was to carry out actual field trials on a typical cable. As the cable was proposed to be tested to destruction, working cable could not be used, so it was necessary to install a suitable length of non-working cable in a trench excavated in rock.

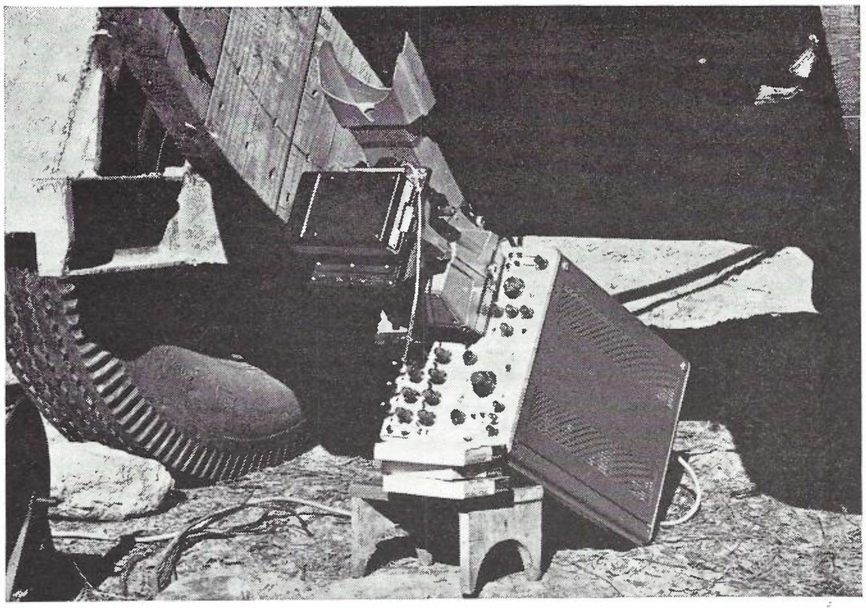


Fig. 1. — Tektronix Type 564 Cathode Ray Oscilloscope with Storage Screen and Polaroid Camera. Screened leads in bottom L.H. corner connect the C.R.O. to the geophones.

Fig. 2 — Four Taxco Geophone Transducers 2 Vertical, 2 Horizontal. Recording unit on the left used to trigger the C.R.O. Cambridge Vibrograph in the background.

* Mr. Lette is Engineer Class 3, Primary Works, Sydney. See Vol. 19, No. 2, P. 175.

Fig. 3. — L. to R. Centre, Backfilled Excavation; L. of Centre, Geophones and Vibrograph. Holes already drilled indicated by wooden plugs.

A spare 63 yard length of 8 tube non layer plastic jacketed coaxial cable was installed in a 4 feet deep trench excavated at Bargo in the vicinity of the Sydney-Melbourne coaxial cable crossing of the Nepean River. The cable was surrounded by 6 in. cover of sand and then backfilled using the excavated material. The backfill was watered and well rammed and the top of the trench was sanded for easier identification (see Fig. 3). The cable ends were then removed and the cable tested with the pulse echo tester and the high voltage tester. After testing, each tube was placed across a High Voltage Tester and remained there for the duration of the investigation.

At right angles to the trench, holes were drilled at distances ranging from 5 feet to 50 feet from the cable. These holes were later charged with explosives varying from 1/6 lb to 2 lb of AN"60" and detonated individually.

The three geophones were placed on the rock at the side of the trench (see Fig. 4), and testing commenced using 1/6 lb of AN"60" at a distance of 5 feet, a count down preceded each blast and at 10 seconds before the detonation, the eight high voltage testers were energised to 4000 volts, with one operator to every two machines. These operators then observed the H.V. testers until a few seconds after the blast, and reported to the testing officer any fluctuations in the voltage readings.

EXPLOSIVES

The generally accepted definition of an explosive is as follows:

"A solid or liquid substance or mixture which on the application of a suitable stimulus to a small portion of the mass, is converted in a very short interval of time into another more stable substance, largely or entirely gaseous, with the development of heat and high pressure."

Blasting powder has been mainly superceded by the gelatinous type of high explosive, for general small scale excavation work. The gelatinous type of explosive is supplied as a wrapped waxed paper cartridge and is available in either the

(a) sodium nitrate or

(b) ammonium nitrate grades.

The sodium nitrate grades are classified according to the percentage of nitroglycerine they contain. For example, SN 60% is a sodium nitrate gelignite containing 60 % nitroglycerine.

Ammonium nitrate on the other hand contains much less nitroglycerine and the strength is made up by the ammonium nitrate which is itself an explosive. Ammonium nitrate grades are classified according to their strength equivalent to the sodium nitrate grades. For example AN"60" is an ammonium nitrate gelignite which, although it only contains 32% nitroglycerine, is equivalent in strength to SN 60% which contains 60% nitroglycerine.

As the ammonium nitrate grades contain much less nitroglycerine they are much cheaper than the sodium nitrate grades consequently the ammonium nitrate grades are the most commonly used.

Of the AN grades AN"60" is the one most used on general excavation work and is characterised by high strength, high density and good water resistance properties.

The cartridge size used during the test at Bargo was 1 in. diameter by 8 in. long, each stick weighing approximately 5 ozs. Consequently 1/6 lb represents approximately ½ of one of the sticks, and 1/3 lb represents 1 stick.

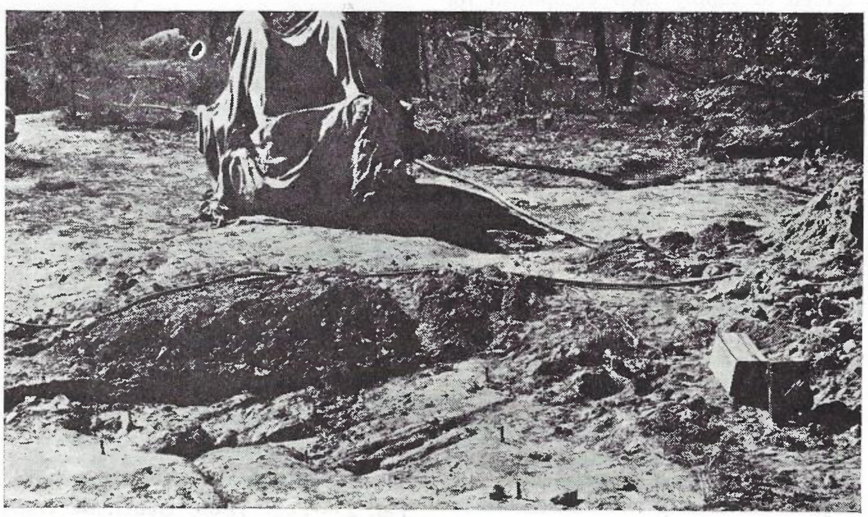


Fig. 4 — C.R.O. and Operators Behind the Tarpaulin Covered Cable Trailer. Right of centre geophones on edge of backfilled excavation.

TABLE 1: EXPLOSIVE CHARGE — DISTANCE — RESULTANT PARTICLE VELOCITY

Test No.	Explosive Charge (lbs.)	Distance (Feet)	C.R.O. Sensitivity (Volts/cm)	Component Voltages			Resultant Voltage (Volts)	Resultant Velocity (in./sec.)
				V_I (Volt)	H_T (Volt)	H_L (Volt)		
1	1/6	25	0.2	0.214	0.1	0.12	0.26	0.7
2	1/6	15	1.0	0.20	0.08	0.16	0.27	0.73
3	1/6	10	1.0	1.1	0.24	0.28	1.12	3.02
4	1/6	5	10.0	8.8	0.4	0.4	8.82	23.8*
5	1/3	23.3	1.0	1.0	0.04	0.4	1.04	2.8
6	1/3	13	5.0	4.75	0.05	4.95	6.86	18.5*
7	1/3	8	10.0	15.0	0.1	0.1	15.0	40.5*
8	1/3	3.3	10.0	20.0	1.2	0.4	20.1	54.2*
9	1/2	23.5	5.0	5.0	0.2	0.2	5.1	13.8*
10	1/2	13.5	10.0	25.0	0.8	3.2	25.3	68.5*
11	1/2	8.5	10.0	40.0	—	—	40.0	108.0*
12	1/2	4	10.0	10.0	—	—	10.0	27.1*
13	1/6	50	0.2	0.4	0.078	0.08	0.41	1.1
14	1/6	40	0.5	0.65	0.06	0.195	0.68	1.84
15	1/6	30	2.0	0.16	0.08	0.4	0.44	1.19
16	1/6	20	5.0	0.1	0.1	0.4	0.42	1.13
17	1/6	19	2.0	0.04	0.12	0.1	0.16	0.43
18	1/6	10	5.0	6.5	0.2	0.45	6.51	17.6*
19	2/3	50	5.0	0.05	0.1	0.15	0.19	0.53
20	2/3	40	1.0	0.4	0.22	0.3	0.55	1.48
21	2/3	31	—					
22	2/3	20	2.0	0.54	1.0	0.24	1.13	3.05
23	2/3	16	5.0	0.4	1.0	0.4	1.23	3.32
24	1	13.5	10.0	1.4	1.0	2.5	3.04	8.21
25	1	50	1.0	0.08	0.2	0.45	0.46	1.24
26	1	40	1.0	0.65	0.4	0.35	0.84	2.27
27	1	30	5.0	2.0	0.2	0.2	2.02	5.5
28	1	25	10.0	0.3	0.3	0.3	0.52	1.4
29	1	21	5.0	0.4	0.4	0.1	0.58	1.57
30	2	50	1.0	0.2	0.35	0.69	0.86	2.32
31	2	40	1.0	1.55	0.47	0.36	1.66	4.5
32	2	31	10.0	0.6	2.0	0.4	2.12	5.72
8A	1/3	23	2.0	0.22	0.8	0.2	0.85	2.29
12A	1/2	30	2.0	0.16	0.16	0.32	0.39	1.05
19A	2/3	50	1.0	0.08	0.12	0.28	0.31	0.84
12B	1/2	21	5.0	0.15	0.5	0.25	0.58	1.56
18A	1/6	15	2.0	0.1	0.4	0.06	0.41	1.11
21A	2/3	25	2.0	0.2	0.2	0.4	0.41	1.11

* Geophones bounced

TEST SITE

The requirements for a site were:

(i) That it be isolated because of the noise problem.

(ii) That it be accessible.

(iii) That the rock be a continuous sheet for at least 60 feet on each side of the cable trench.

The site at Bargo fulfilled all these requirements as well as being within a few hundred feet of a manhole on the Sydney-Melbourne coaxial cable. By utilizing the local order wire in the manhole, a communications set-up was established which simplified logistic support.

Rock Analysis

A sample of the rock was forwarded to the N.S.W. Department of Mines who reported as follows:

"The sample of rock from Bargo submitted for examination has the following composition. Quartz arenite (sandstone) consisting essentially of rounded to sub-rounded grains of quartz in a matrix of clay and iron oxide. Secondary overgrowth of quartz grains is common, in some cases resulting in the fusing of adjacent grains. Average grainsize is approximately 0.3 m.m. The specimen examined indicates that the rock is fairly friable."

The rock from the above analysis is a soft type. Soft rock will transmit shock waves much further than does hard rock, consequently any recommendations based on this rock may be used safely for harder types of rock.

TEST RESULTS

The first important result was that a charge of ½ lb at 5 feet from the cable created a split in the rock with a permanent displacement of ground into the cable trench. No damage resulted to the cable but obviously ½ lb at 5 feet is dangerous, not from ground velocity but from physical displacement. As no displacement occurred when ⅓ lb. was fired 5 feet from the cable the critical charge is somewhere between ⅓ lb and ½ lb. Taking the lower limit of ⅓ lb and using a safety factor of 3 a safe charge of 1/9 lb 5 feet from the cable can be deduced. The balance of the testing continued without incident and Table 1 shows the test results.

After the programme was completed the cable still had not recorded any damage. It was intended to test the cable to destruction but as the large charges were exceeding the limits of the testing instruments at close range, there was no point in increasing the charges further until the cable failed, for it would be impossible to know at

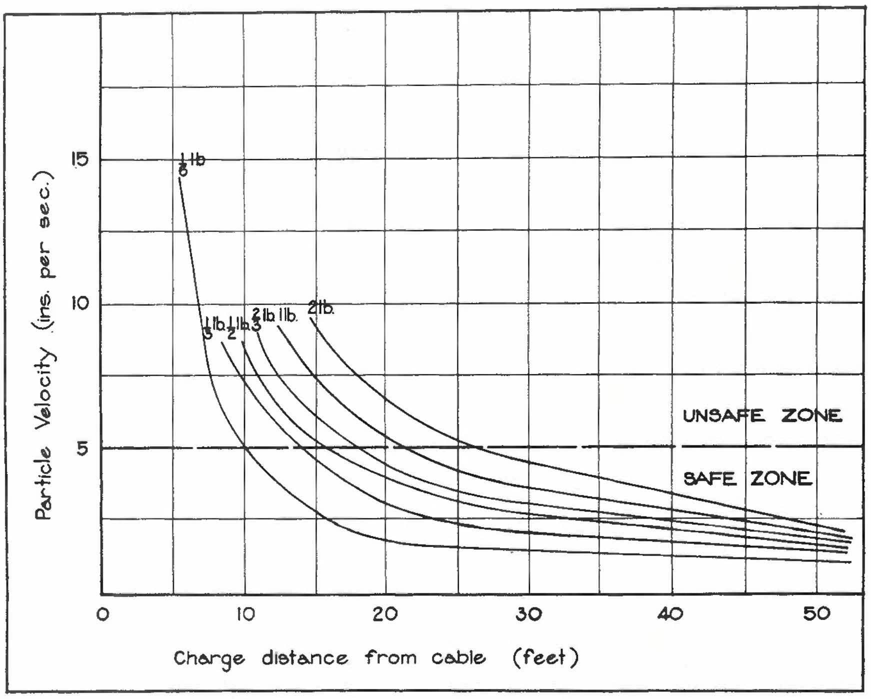


Fig. 5 — Graph Showing Particle Velocity-Distance Curves for Various Sized Explosive Charges.

what particular velocity failure occurred.

The cable was subsequently withdrawn and examined. It was sound with no visible marks or indentations. After final electrical tests on the tubes it was resealed and transported back to the store.

The graph in Fig. 5 was produced in conjunction with the Mines Department of N.S.W. and represents Particle Velocity—distance curves for various size charges, based on the results from the oscilloscope readings.

The highest particle velocity recorded at the cable was 8.21 inches/second which not only did not effect the tubes but left the cable sheath unmarked. Obviously the threshold for a damaging ground velocity would be higher than 8.21 ins./sec. However in the interests of safety to the cable a lower limit should be adopted and in accordance with this reasoning a limit of 5.0 ins./sec has been selected. It is freely admitted that there is not sufficient evidence to arrive at a soundly based statistical figure. This would require many weeks of testing in a variety of locations, and was beyond the scope of this initial investigation. However until further work is done a particle velocity limit of 5.0 ins./sec. is regarded as reasonable. This limit is undoubtedly conservative but should be a safe one and also a practical one in that the size of charge permitted is of sufficient weight for it to be effective.

S.A.A. Recommendations

If blasting operations are to be carried out near both coaxial cables and structures, care will need to be exercised in adopting the correct upper limit. The Standards Association of Australia (CA 23, 1967), have recommended that structures be subjected to particle velocity values not greater than 0.75 ins./sec. Consequently when blasting under these conditions the size of the charge should be such that any building or structure will not be subjected to particle velocities in excess of 0.75 ins./sec., which is, and this must be emphasised, a comfort level and not a damage threshold.

Subsequent Tests

Further tests were carried out at Balmain in November, 1967, and at Mona Vale in March, 1968. These results verify the figures obtained at Bargo.

RESULTS USING VIBROGRAPH

Comparison checks were made with the Cambridge Vibrograph and its results were checked against the oscilloscope geophone combination. Within 20 feet of a one pound charge the vibrograph results did not correspond with the oscilloscope readings, also the stylus on film recordings produced by the vibrograph were nearly impossible to read due to the high frequencies present. However, beyond 20 feet the recordings were decipherable and there is no doubt that this instrument would be satisfactory under certain conditions, as illustrated by the following example.

At Goulburn N.S.W., in June 1969 a series of vibration readings were taken with the vibrograph, for charges ranging up to 60 pounds of explosives. At 150 feet from the 60 lb charge the recordings were easily read, typical results being vertical vibration 0.002 inches at 50 c.p.s., horizontal longitudinal vibration 0.002 inches at 50 c.p.s. and horizontal transverse vibration 0.004 inches at 50 c.p.s. The resultant vibration was calculated to be 0.005 inches at 50 c.p.s. By reference to the nomogram shown as Fig. 6 this vibration is shown to be equivalent to a particle velocity of 1.5 inches/second.

A description of the Cambridge Universal Vibrograph and a typical example of a recording has already been given in the Telecommunication Journal of Australia, Vol. 19, No. 2, June 1969 (Ref.1).

CONCLUSION

The tests proved that reasonably sized explosive charges may be detonated, with safety, near coaxial cables, subject to the following safeguards:

(i) No explosive should be detonated within 5 feet of the nearest edge of the cable trench. Between 5 feet to 10 feet the charge should not exceed $\frac{1}{9}$ lb of AN"60". At 10 feet from the edge of the cable trench the charge size should not exceed $\frac{1}{6}$ lb. of AN"60" or its equivalent.

(ii) The particle velocity curves shown as Fig. 5 should be used to determine a safe explosive weight. (This weight only refers to the instantaneous charge, and if millisecond delay detonators are used a number of charges each $\frac{2}{3}$ the weight of the instantaneous charge may be detonated at the same time. The number of charges is limited only by the number of detonators in the range).

(iii) Notwithstanding (i) and (ii) the cable is in hazard if any rock, part rock or soil is permanently displaced into the cable trench (termed "cratering"), the charge size must then be reduced. ("Cratering" is also a possibility on the bottom of the cable trench if the charge is within 10 feet of the cable trench and is **deeper** than the cable trench. The top surface of the cable trench should be carefully observed for indications that "cratering" may be occurring.)

(iv) In other than built up areas the upper limit for particle velocity, at the cable, of 5.0 ins./sec. is not to be exceeded.

(v) In built up areas no structures or buildings to be subjected to particle velocities in excess of 0.75 ins./sec. (As laid down in the S.A.A. Explosives Code, Australian Standard CA23-1967 Section 10.)

(vi) The rock at the test site was a continuous sheet without faults. If faults exist and run between the cable trench and the explosive location, care will need to be exercised and the weight of charge may need to be reduced.

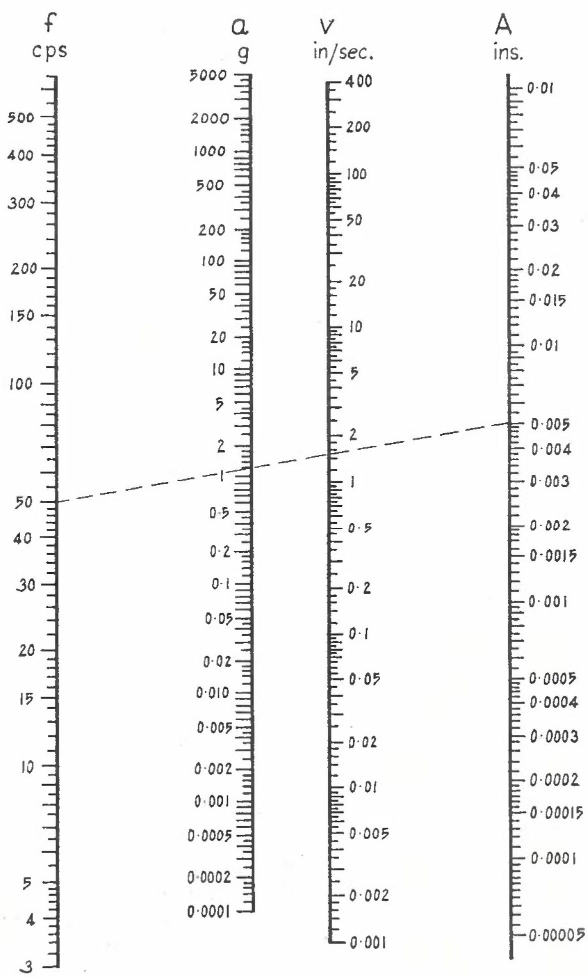


Fig. 6. — Nomogram Showing the Relationship Between Frequency (f), Acceleration (a), Ground Velocity (v), and Amplitude of Vibration (A). The example indicates that a vibration of A = 0.005 inches at a frequency of f = 50 c.p.s. is equivalent to a particle velocity of v = 1.5 inches/second.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the valuable assistance given to him by the Supervising Engineer, Primary Works Sydney, Divisional Engineer Goulburn Regional Works and Services and Divisional Engineer, Transmission Planning (Measurements).

REFERENCE

1. M. F. Lette, 'Installation of Lead Sheathed Cables on Bridges'; Telecom. Journal of Aust., June 1969, Vol. 19, No. 2, P. 127.

SYSTEM AFM402 — SERVICE ASSESSMENT EQUIPMENT

*F. M. SCOTT, A.M.I.R.E.E. (Aust.)**

INTRODUCTION

An adjunct to every telephone switching system is the means of evaluating its performance in service. Previous articles on System AFM402 in Vol. 19 No. 1 and No. 2 of this Journal explained the facilities of the system and outlined the functions of the various operating positions, relay sets, and racks. This article describes the service assessment facilities and equipment. To fully appreciate the scope of the facilities provided it is desirable that the reader be familiar with the contents of the previous articles on System AFM402.

BLOCK DIAGRAM

Fig. 1 shows a block diagram of the service assessment equipment and its relationship with the manual assistance positions. The connection of the equipment is flexible as all tappings are arranged via I.D.F. jumpers. Much of the data required is recorded on statistical meters some of which can be reset to zero after the reading is noted. The Service Assessment Position is staffed by experienced traffic personnel and through lamp indications provides a direct means of assessing traffic handled by trunk assistance and special service position operators.

* Mr. Scott is Engineer Class 3, Internal Equipment, Queensland. See Vol. 19 No.1, P. 77.

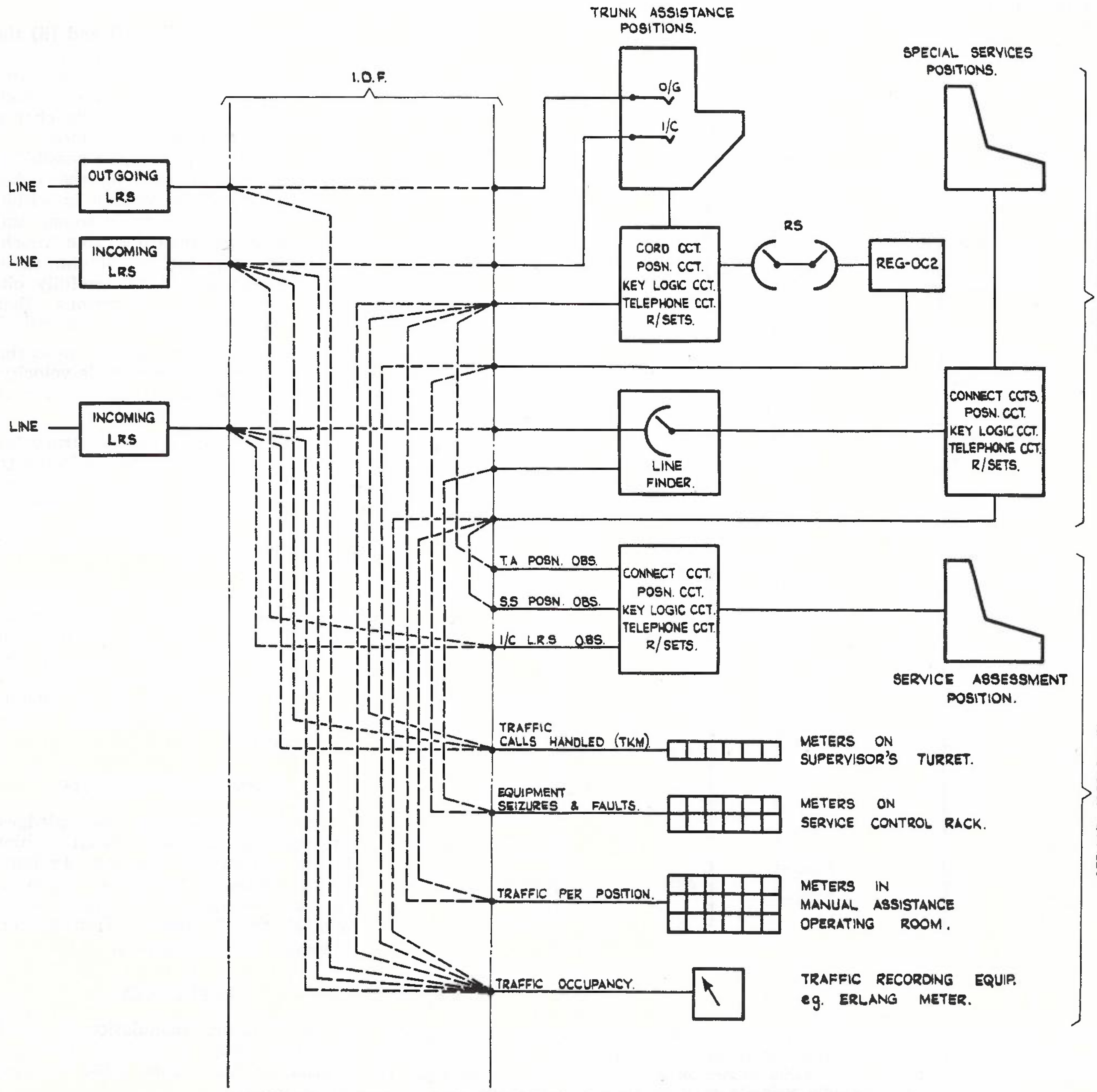


Fig. 1. — System AFM 402 Service Assessment Block Diagram.

SCOTT — System AFM 402 Service Assessment

CALL COUNT METERS

Cyclometer type meters are provided on the Supervisor's turret and also in the service control room or service assessment rack (RACK-XOC) to record call count registrations. Some of these provide continuing readings while others are mechanically resettable and may be restored to zero on a daily, weekly or monthly basis following the recording of the readings in a journal. Meters on the supervisor's turret are as follows:

* Trunk Assistance Total Calls Answered
* Trunk Assistance Long Wait Calls
Trunk Assistance Calls Offered
Trunk Assistance Effective Demand Calls
Trunk Assistance Effective Revertive Calls
* Special Services Total Calls Answered
* Special Services Long Wait Calls

On each of the indications marked * above, two meters are provided—one continuous and the other resettable.

The reading provided by the Total Calls Answered meters is a summation of all calls answered by the manual assistance operators. The supervisor pre-determines a time commitment for answering trunk assistance and service assistance traffic and sets keys on the supervisor's turret to signal these requirements to the Gating Control relay sets. Durations of 10, 20 and 30 seconds may be set. The Long Wait Calls meters record the number of calls which waited in excess of the predetermined speed of answer time. The Calls Offered meters would normally indicate a higher reading than the Total Calls Answered meters and the difference between the two registrations indicates the number of calls abandoned before being answered by an operator. The Effective Demand and Effective Revertive Calls meters provide a means of determining the ratio of demand revertive traffic handled.

In the Service Control equipment, provision is made for 80 meters. Some are permanently wired to record particular data, while others are extended to the I.D.F. where they may be jumpered to various TKM leads as required. Permanent meters are provided for the following counts:

REG-OC2 seizures (one per REG)
REG-OC2 time-outs after finish key (one per REG)
RSM time-outs after identification (one per RSM)
RSM time-outs after register selection (one per RSM)
CSM total time-out (one per CSM)

The permanently connected meters on the supervisor's turret and in the service control equipment provide indications of the more important TKM, RSM and CSM readings. Many other leads originate in line relay sets, cord circuit relay sets, registers and markers and these are wired to the I.D.F. for jumpering to the spare meters provided in the service control equipment as required.

Line relay sets are provided with all or some of the following TKM leads depending on whether they are incoming, outgoing or bothway in operation:

Incoming Calls Offered.
Incoming Calls Answered
Outgoing Calls Attempted
Outgoing Calls Effective

Cord circuits on Trunk Assistance Positions indicate the following:

Effective Demand Calls
Effective Revertive Calls
Demand Calls Answered
Outgoing Calls Attempted—Ans. side
Outgoing Calls Attempted—Call side

The operator's registers (REG-OC2) provide the following data:

Total Register Seizures
Total O/G L.R.S. Seizures for 20 ips sending
Total O/G L.R.S. Seizures for 10 ips sending
Time-outs after finish key pressed
Time-outs before finish key pressed
OPR settings for disconnect idle
OPR settings for disconnect busy or congestion

Special service position connect circuits provide the following indications:

Enquiry Connect Circuit—
(i) Total Calls Answered
Complaints Connect Circuit—
(i) Total Calls Answered
(ii) Total Calls Extended

The line finder markers (CSM) provide indications of time-outs individually and also as a group.

The TKM indication is an earth pulse of 80 to 100 mS duration.

CIRCUIT OCCUPANCY LEADS

Each traffic carrying relay set has one or two leads used to indicate circuit occupancy. These TKT leads are brought out to the I.D.F. where they are commoned in groups and jumpered to equipment designed to read traffic occupancy. When each device is engaged on a call, a 100,000 ohm earth is connected to its TKT lead. On a 50 volts d.c. supply this will cause half a milli-ampere to flow in the 100 K ohm resistor. By combining a number of TKT leads and reading the number of half milli-amperes of current flowing in the common wiring by using a suitably calibrated meter, a direct reading of circuits occupied is obtained. Alternatively, the current flow may be recorded on a moving tape to provide a permanent record of the traffic density over a period of 24 hours, or longer if necessary.

The following TKT leads are extended to the I.D.F.:

Two per T.A. position Cord circuit
(i) Effective (revenue earning) time
(ii) Total Occupation time
One per Register OC2
One per S.S. position enquiry connect circuit
One per S.S. position complaints connect circuit
One per line relay set
One per service line relay set
One per test tone relay set
One per conference relay set

SERVICE ASSESSMENT POSITION

The Position Observation Turret provides facilities for three types of service assessment:

(i) Trunk Assistance and Special Services position observations
(ii) Cord and Connect circuit observations on the T.A. and S.S. positions
(iii) Incoming line relay set observations on routes terminating on the T.A. or S.S. positions.

The capacity of the equipment is 20 T.A. positions, 20 S.S. positions and five incoming line relay sets. All connections are jumpered via the I.D.F. Jumpering to the position circuits is done as part of the initial installation and would remain virtually undisturbed during the life of the exchange, but the jumpering of the five line relay sets is intended to be temporary so that different groups of five may be allocated from time to time to increase the range of the sample.

TURRET

The face layout of the key panel on the Position Observation Turret is shown in Fig. 2. All keys are of the ERGA type. Some have combined key and lamp functions while others provide a lamp display only. Five categories of keys are provided:

Primary Access Keys: These are the first five keys in the bottom right hand row. The first two of these enable a lamp display of Positions Staffed—either for T.A. positions or S.S. positions—to be given on the 20 amber lamps in the two key strips immediately above. The next three keys give access to the T.A. positions, the S.S. positions, or the five line relay sets respectively.

Secondary Access Keys: Having determined that T.A. positions or S.S. positions are to be observed, the particular position must be selected. The 20 keys designated Positions 1 to 20 provide connection to the individual positions. If, however, line relay sets are under observation, one of the five L.R.S. 1-5 keys is used to connect to the desired line.

Tertiary Access Keys: When a position observation is in progress, on either a T.A. or S.S. position, a particular cord or connect circuit may be selected for detailed assessment. This switching is performed by the T.A. position 1-6 keys in the bottom row on the lower left hand side, or the S.S. Enquiry 1-2 or S.S. Complaints 1-3 keys in the row above.

Indicating lamps: A lamp indication is provided for each speaking point on an operating position so that the observer may associate a conversation with a particular connect circuit, order wire, exchange line etc. An indication is also given of each major key operation on the position under observation and also an appearance of the supervisory lamps. The speaking points are indicated by the amber lamps in the lower left hand group and key and supervisory lamp indications appear in the lower centre group.

Miscellaneous: These are the keys in the upper turret panel. They comprise some control keys immediately below the dial and a group of six lamp indications on the left of the panel.

In addition to the keys, the following apparatus is provided:

(i) A call pilot lamp on the top of the turret to indicate calls awaiting answer.

(ii) A 10 ips dial for originating calls on the exchange line.

(iii) A 24 hour digital clock indicating the time of day.

(iv) Two telephone jacks for the operator's headset or handset (mounted on front edge of table).

(v) A buzzer to give an audible indication of waiting calls (mounted inside the turret).

OPERATION OF TURRET

Before the connect keys on the turret will function, a headset or handset must first be plugged into one of the dual telephone jacks to operate the position staffed relay in the position relay set. Three colours of lamp plates are employed each with a distinctive meaning:

Green—indicates an operated access key function.

Amber—indicates a call or supervisory lamp.

Red—indicates an operated control key function.

Keys which have no green or red colour plates have no key switching functions. These are fitted with amber plates and are used for lamp displays only. The three Set Observation keys in the primary access group, i.e. Observe T.A. Positions, Observe S.S. Positions and Observe Incoming L.R.S. function in a mutual release chain and

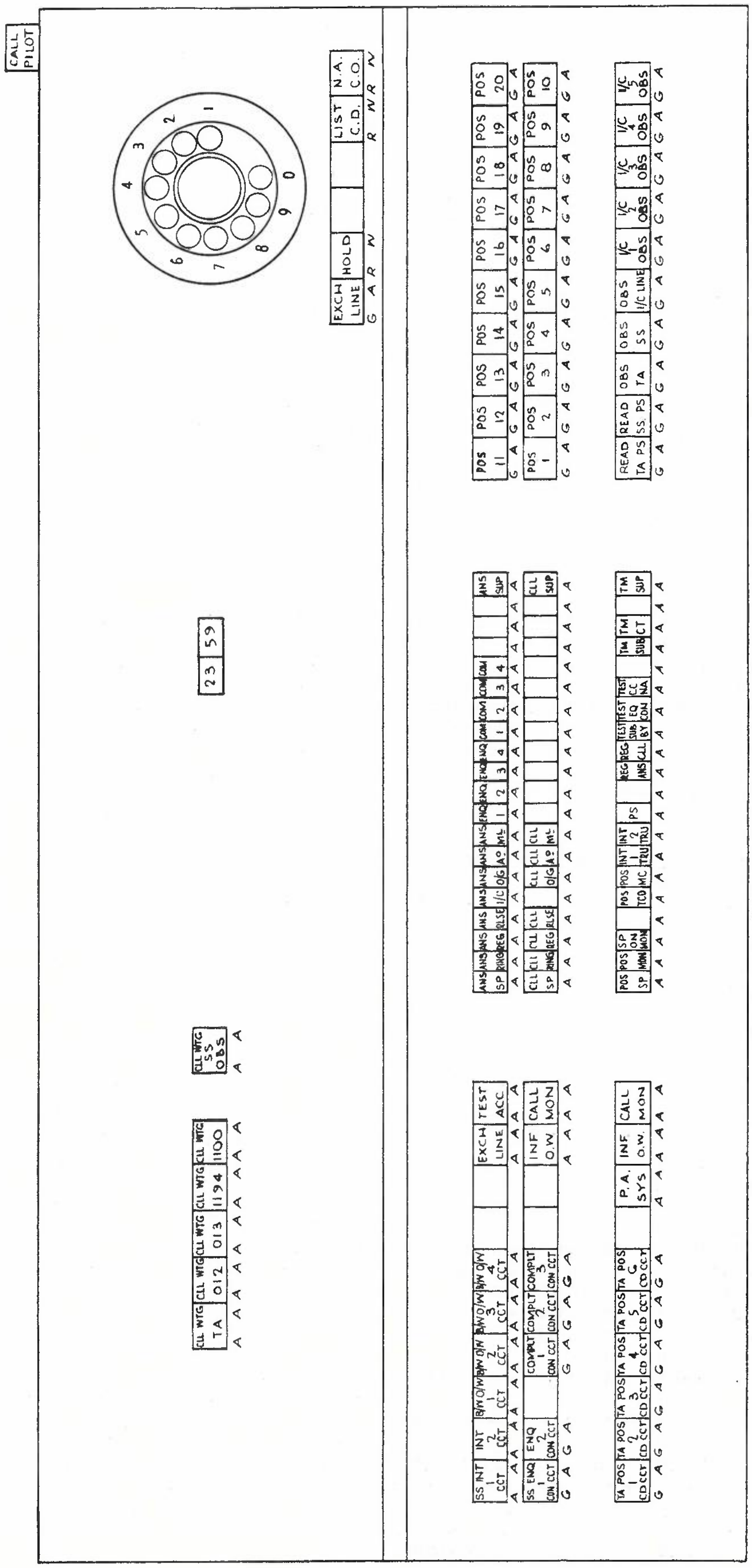


Fig. 2. — Position Observation Turret Key Panel Layout.

only one of the three can be operative at a time.

The Position 1-20 keys are common to both T.A. and S.S. positions. Their association with either type of operating position is determined by the operation of the Observe T.A. Positions and Observe S.S. Positions keys.

The turret is designed for single finger operation; i.e. it is not necessary to simultaneously press two or more keys to set a particular function. The layout provides the most efficient arrangement for operating and viewing. The keys in the lower right hand sector are those most frequently used. They all have switching functions and are placed in a favourable location for manipulation by the operator's right hand. A smaller number of keys which require less frequent operation is included in the group on the lower left hand sector. These are in the most convenient position for the operator's left hand. The keys in the lower centre group provide lamp indications without any switching functions and are thus not obstructed by hand move ments over the left and right hand groups. The exchange line keys and the associated dial are placed in the upper right hand panel.

POSITION OBSERVATIONS

Suppose T.A. position number 1 is to be observed. The operator would first press the Read T.A. Positions Staffed key to determine whether the position is currently staffed. If it is not staffed, the lamp in the Position 1 key will not light. In these circumstances the observer may select another position. The amber lamps of the staffed T.A. positions in the 1-20 group will light corresponding to the staffing pattern. Both Read keys have non-locking functions and therefore all positions Staffed lamps will extinguish when the key is released. Assuming that Position 1 is staffed, the Observe T.A. Positions key is now pressed followed by the Position No. 1 key. Both of these keys have locking functions, and although the keys themselves restore under spring tension, the functions remain operated as indicated by the glowing of the green lamps. T.A. position No. 1 is now connected. The amber lamps in the bottom left hand strip and the three centre strips now give a visual indication of the progress of operating on the position nominated. On a T.A. position nine speaking points are provided as follows:

Cord circuits 1-6
Call Monitor circuit
Outgoing order wire to Routing Information
Public Address System

As a T.A. operator can speak to only one point at a time, no more than one of the nine amber lamps can be glowing. The three rows of lamps in the lower centre group indicate key operations and supervisory signals in the position and cord circuits. The lower row is associated with the position circuit and provides indications as follows:

A speak key operated
A monitor key operated
Speak on Monitor key operated
T.C.O. Key operated
M.C. Key operated
Interception 1 through key operated
Interception 2 through key operated
Indication of position staffed
Register coupled to answer side
Register coupled to call side
Test Access Sub. Busy Lamp
Test Access Equipment Congestion Lamp
Night Alarm from cord circuit
Call timer connected for subscriber
Call timer connected for coin telephone
Call timer supervisory lamp

The top row is associated with the answer side of the cord and connect circuits and the following lamp indications are provided:

Speak answer key operated
Ring answer key operated
Register connected on answer side
Release answer side key operated
Answer side used for incoming call
Answer side used for outgoing call
Automatic type call discrimination
Manual type call discrimination
Call category enquiry 1-4
Call category complaints 1-4
Answer supervisory lamp

The middle row signals call side indications as follows:

Speak call key operated
Ring call key operated
Register connected on call side
Release call side key operated
Call side in use for outgoing call
Automatic type call discrimination
Manual type call discrimination
Call supervisory lamp

When a cord or connect circuit speak key is operated on the position under observation the lamp indications for that particular cord circuit are signalled to the observation turret. These of course will change as the telephonist switches from one cord or connect circuit to another. The amber lamps in the left of the middle and lower rows on the left hand side indicate which cord or connect circuit is supplying the lamp display.

If the observer decides to stay across one particular cord or connect circuit, the appropriate tertiary access key is operated. The speech leads are switched to the nominated cord or connect circuit and lamp indications relevant to that particular circuit will appear on the observation turret. The telephonist's voice will be heard only if the cord or connect circuit speak key is operated by the telephonist. At this stage three green lamps will be glowing as follows, assuming that cord circuit 3 is being observed:

Observe T.A. Positions
Observe Position No. 1
Observe cord circuit No. 3

The cord and connect circuit keys are arranged in a mutual release chain to enable the observer to switch from one to another by a single key operation. If another position key say Position 2 is operated while cord circuit 3 on Position 1 is connected, the control circuit will release the observe cord circuit function before allowing the change from Position 1 to Position 2. Similarly, if the Observe S.S. Positions key is operated when cord circuit 3 on T.A. position No. 1 is under observation, the observe cord circuit, the Connect Position 1 and the Observe T.A. positions functions must all restore to normal before the logic control circuit will permit switching to Observe S.S. positions.

A telephonist on a fully equipped Special Services position may speak to 15 points as follows:

Enquiry connect circuits 1-2
Complaints connect circuits 1-3
Interception Circuits 1-2
Bothway order wires 1-4
Test Access circuit
Incoming O.W from T.A. positions
Bothway exchange line
Call monitor circuit

When an S.S. position is under observation the operation of any of the speak keys will light one of the 15 amber lamps in the S.S. group on the lower left hand sector. The observer may thus associate a conversation with a particular source. Calls coming to the S.S. position via the line finder stage are classified as either enquiry or complaints and each group is further subdivided into four classifications to indicate the service level or zone of origin. These call classifications are indicated on eight lamps in the answer side group.

The first three lamps on the top panel are appearances of the exchange call waiting pilot lamps covering the T.A. positions (Levels 011, 010 etc. and direct trunks) and the four main inlets to the S.S. position for trunk enquiry, directory information, time and complaints. The sixth lamp lights when an S.S. position is being observed and one or more of the calls waiting in the S.S. group can be answered on that particular position. Thus if an S.S. position has enquiry type connect circuits only, the sixth lamp will light when enquiry calls are waiting but not if the only calls waiting are in the complaints group. At large exchanges, each S.S. position may not have access to all the incoming lines in a group. A typical case would be where local complaint calls terminate on one suite of positions, while complaints traffic from other zones is handled by a separate suite. In this condition, the sixth lamp would light when a call arrives from the particular sub-group to which the position is connected.

LINE RELAY SET OBSERVATION

The operation of the Observe Incoming L.R.S. key releases any other observe key functions already operated (through the mutual release chain) and switches the five selected line relay sets to the observation equipment. If any of these relay sets are already engaged on a call the associated amber lamp in the Observe L.R.S. 1-5 keys will light with a steady glow. When a new incoming call arrives, the amber lamp will glow when the relay set is seized and remain as a steady indication until the call is in the final gating stage. The amber lamp will then flash at the FL.1 periodicity (0.2 secs. on, 0.2 secs. off). When the call is answered by the telephonist the lamp will revert to a steady glow for the duration of the call.

The observer may connect the listening circuit to any one of the five incoming lines. Ringing tone will be heard when the relay set is seized followed by the telephonist's voice when the call is answered. The speed of answer on individual calls on various incoming routes may thus be determined. As each incoming line is connected to the observer, the green lamp in the operated key will light indicating that the key connect function is operative.

MISCELLANEOUS FUNCTIONS

Provision is made for the termination of a bothway automatic exchange line on keys adjacent to the dial. An incoming call will flash the amber lamp in the Exchange Line key, light the call pilot lamp and sound the turret buzzer. The call is answered by pressing the Exchange Line key. This will cause the green lamp to light and the amber lamp to extinguish. The Hold key places a holding loop and V.F. termination across the line and for ease of operation a mutual release chain is included between the Exchange Line and Hold keys. The red lamp in the Hold key lights when its function is operative. On an outgoing call, the dial is used to establish the connection to the wanted number.

The operation of any Observation Connect key extends the observers listening circuit to the device selected. If listening is not required, the circuit may be disconnected by pressing the Listen Cut Off key. The red lamp in this key will light when the function is operative.

Each incoming exchange line call will cause the buzzer to operate. The observer may disconnect it temporarily by pressing the Buzzer Cut Off key. The red lamp in the key will light as a reminder that the function is operative but will extinguish when the Exchange Line key is pressed to answer the call. This also restores the buzzer circuit so that the buzzer will sound on the next incoming call.

EQUIPMENT

The relays associated with the Observation Turret are distributed over four relay sets, as follows:

Key logic relay set OKR-XOC-KO
Miscellaneous Connect Circuit R/S SNOR-XOC-G
Position circuit R/S OPR-XOC-S
Telephone circuit R/S OTR-XOC-V

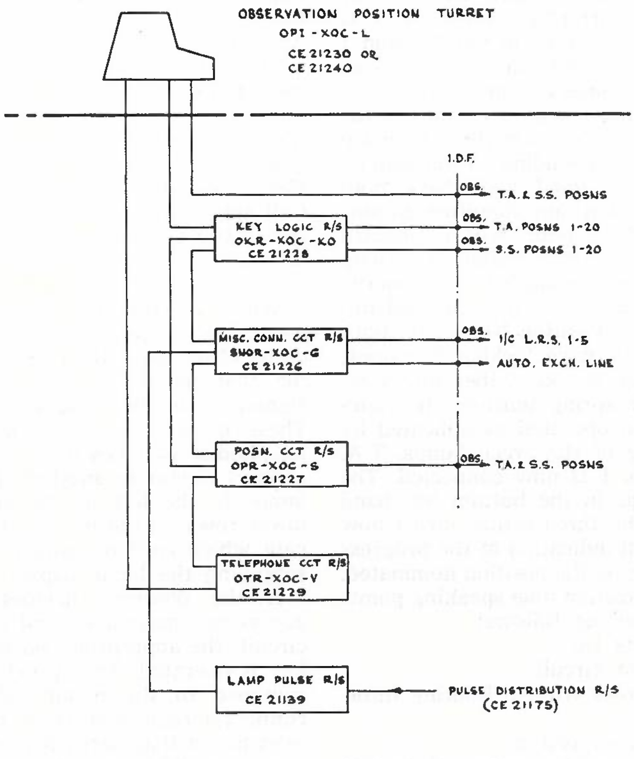
These four relay sets together with other service control relay sets and meters are mounted on Rack XOC. Fig. 3 shows a block diagram of the observation equipment.

The key logic relay set contains 69 relays which perform all the control, memory and logic functions associated with the keys. This relay set is an intermediate stage between the turret keys and the other observation relay sets and operating positions.

The Miscellaneous Connect Circuit relay set includes the relays for the bothway exchange line and those required for the observation of the five incoming line relay sets.

The Position Circuit relay set controls the switching of the speaking and listening wires, the position staffed functions lighting of the pilot lamp, the buzzer cut off function and the supervision of battery supply to the turret and other relay sets.

The Telephone Circuit relay set provides a two wire speech circuit and a four wire listening circuit. Voices from these sources may be heard simultaneously without any cross interference. A resistor type combining network blends the speech and listening circuits with side tone from the Observers telephone transmitter. The combined received speech signals are amplified in an Amplifier Type 2 then applied to the observers telephone receiver. In a manual assistance position, there is a transmission level difference of 9 dB between the observation tapping points in the SNOR and OTR relay sets. On the Observation Position this would result in a 9 dB difference in level on observations made on position circuits and on cord or connect circuits. To compensate for this the OTR-XOC-V relay set includes a 9 dB switchable pad which is in circuit for cord and connect circuit observations but removed for position observations.



NOTE : THE OBSERVATION RELAY SETS MOUNT ON RACK XOC. (CE21242)

Fig. 3 — Position and Incoming Line Observation Block Diagram.

CONCLUSION

The service assessment equipment designed for System AFM402 provides a comprehensive coverage of all aspects of manual assistance working. Measurement of traffic flow can be obtained as an instantaneous indication on the TKT leads while statistics on calls handled, type of traffic, time-outs etc. are available from the TKM meters. Calls may be observed on a random basis using the line tapping circuits which enable the observation to commence at the moment ringing tone is connected. Particular positions, or telephonists stationed at particular positions, may be observed via the position observation access circuit. Cord or connect circuits on any T.A. or S.S. position may be nominated for observation of random subscribers traffic.

An abridged version of the Observation Turret has also been developed for use where the full facilities are not required. The missing facilities include the incoming line relay set observations, the connect circuit observations on S.S. positions and many of the lamps indicating key operations and call categories on the positions under observation. The same relay set equipment is associated with both turrets.

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1. F. M. Scott, 'System AFM402—The A.P.O. Four Wire Cord Type Manual Assistance Centre'; Part 1 Telecommunication Journal of Australia, Feb. 1969, Vol. 19, No. 1, P. 41. Part 2 Telecommunication Journal of Australia, June 1969, Vol. 19, No. 2, P. 136.

TECHNICAL NEWS ITEM

MICROWAVE RADIO LINK TO DARWIN

The Postmaster-General, Mr Alan S. Hulme, has announced that a microwave radio system is to be installed which will link Darwin (population 25,000) in the Northern Territory with the broadband network already providing the trunk telephony and television needs of the major cities of the Commonwealth. The new microwave system will be routed via Katherine and Tennant Creek and link at Mt. Isa, Queensland, with the Townsville-Mt. Isa microwave system which is currently under construction. The Mt. Isa-Darwin microwave system will traverse a distance of about 1,000 miles and include almost 50 repeater stations. The project is estimated to cost about $8 million and completion is scheduled during 1972.

If the project can be completed on schedule the new broadband system will reach Darwin 100 years after the establishment of the first telegraph line to Darwin (from Adelaide) by Sir Charles Todd in 1872—the famed overland telegraph line.

Like the Townsville-Mt. Isa microwave system, the Darwin extension would be capable of providing 960/1200 telephone circuits and could be expanded to provide television relay facilities, if necessary.

The Australian Post Office will be responsible for the overall co-ordination of the efforts of the many different contractors as well as the several Commonwealth, State and Northern Territory authorities who will take part in the construction of this project.

Survey work is already proceeding and contracts for the construction of roads, buildings and the supply and installation of shelters, towers, power plant, radio and test equipment will be let progressively over the next year.

With the completion of the microwave system to Darwin the Australian Post Office broadband network of microwave radio systems and coaxial cables will extend in an unbroken chain from Darwin to Port Hedland in Western Australia over a distance of 6,700 miles.

Since the completion of the first broadband system in Australia in 1959, rapid expansion has occurred and at June 1969 the route distance of microwave systems capable of carrying at least 300 telephone circuits or a television relay will amount to almost 6,000 miles while a further 2,000 sheath miles of coaxial cable has also been installed. The investment in the broadband network will have reached $200 million when the microwave system to Darwin is completed.

SYSTEM AFM402 — SOME INTERESTING CIRCUIT ELEMENTS

*F. M. SCOTT, A.M.I.R.E.E. (Aust.)**

INTRODUCTION.

'There's nothing new under the sun' is a saying often heard these days. Designers in many fields are experiencing increasing difficulty in coming up with new ideas and novel presentation. Architecture, fashion and salesmanship are activities particularly pressed for new approaches. The same comments may be applied to the design of electromechanical circuits. Very little that is entirely new is being added to the technology, but there is ample scope for adaptive design. This involves selecting the best elements available, adapting previous circuit techniques that have been extensively tested and proved, introducing new components, and adjusting circuit design to new facility schedules. The result is a new circuit containing many familiar circuit elements arranged in a different pattern.

The trend in circuit design is towards reliability and more comprehensive facilities and away from limiting conditions such as marginal current, specal adjustment, and relay operation that is not fully sequenced. The circuit element is the building block of circuit synthesis. An understanding of the various circuit elements quickly leads to an overall appreciation of the full circuit. This article explains some of the basic circuit elements used in the design of System AFM402. (Ref. 1.)

SWITCHBOARD CONTROL WIRE.

Two wire switchboards using three pole plugs and jacks usually employ the sleeve wire for testing, seizing and holding of line relay sets. On the Trunk Assistance Position of the Four Wire Cord Type Switchboard this function is performed by conductor 5, which on a 6-pole plug is the fourth ring (the conductors on a 6-pole plug number from one at the tip through to 6 at the sleeve). Essentially the following conditions must be met:—

(i) When idle, no potential should be present on any of the plug conductors except the one used for initial pick-up.
(ii) It should not be possible to over-plug and connect to a working line.
(iii) The potentials used to mark the idle and engaged conditions should be quite distinctive.
(iv) When a cord circuit plug is inserted in a free line jack, both the cord circuit and line relay sets should be seized and the test potential replaced by the busy condition.
(v) Both circuits should restore to normal when the plug is withdrawn from the jack.

The circuit elements used for the c wire between the cord circuit and outgoing line relay set circuits are shown in Fig. 1. An idle L.R.S. is marked with negative battery through the 400-ohm winding of F51. When engaged, earth via 200 ohms of SC1 holds F51 operated over its two windings in series. The potential on the plug and jack c wires is then approximately 7 volts. Blocking of the relay set causes F10 to operate, which open circuits the c wire. Thus the c wire potentials are as follows:—

idle—48 volts negative.
engaged—7 volts negative.
blocked—open circuit.

The cord circuit relay set is marked idle by the operation of S11 when the following conditions exist:—

(i) The OPR fuse is intact.
(ii) The OPR is not blocked.
(iii) The telephonist's headset is plugged into the T.A. position keyshelf, or the position is coupled to the previous adjacent position which is staffed.
(iv) The SNOR is not in use, and all relays with contacts in the operate path of S11 are unoperated.
(v) The call timer is not off normal (i.e., 9.9).

Relay S11 operated connects earth potential via a diode and a 24 volt zener diode to the SC1 relay. The ordinary diode prevents SC1 operating to positive battery pulses, which may be present on the sleeve wire of a working line jack. The zener diode provides a reference point to discriminate between the 7V. and 48V. negative potentials encountered on the c wire. With 7 volts applied to SC1 the zener diode is non-conducting and therefore SC1 remains unoperated. When the c wire potential exceeds 24 volts the diode conducts and current flows in SC1. On a nominal 48 volt supply approximately 24 volts is available to operate SC1 through a circuit resistance of 600 ohms.

The connect relay 1SC2 operates shortly after, and connects a full earth to SC1 shunting the diodes. With 48 volts available on the c wire F51 operates. The resistance of F51 is increased when the 800 ohm winding is included in the circuit. The circuit resistance is now 1400 ohms (plus any resistance present in the exchange cabling), giving a nominal c wire potential of 7 volts. The design allows for up to 50 ohms in the wiring between the SNOR and the plug, and a further 50 ohms from the jack to the line relay set. With the wiring resistance at the maximum limit the c wire voltage is raised to approximately 10 volts, which is still well below the 24 volt point. Even with the exchange voltage at 56 volts the highest c wire potential under adverse conditions does not exceed 12 volts. F51 is made slow to operate to minimise flutter should the plug be inserted into the jack slowly and erratically.

Once the line relay set is seized, F51 operates F10, but the circuit to F51 is last to restore and the F51 relay is isolated from the c wire until the relay set is free for the next call.

If the cord circuit answer plug is used to answer an incoming call before the call plug is required to extend the call to an outgoing line then S11 will be released. Its function is then duplicated by the 2SA2 contacts which operate when the answer plug is inserted into the incoming line jack. Operation of the c wire circuit from then on is as previously described. The SC13 contact unit is included in the circuit to ensure that c wire pick-up cannot occur with SC13 remaining operated from a previous call attempt.

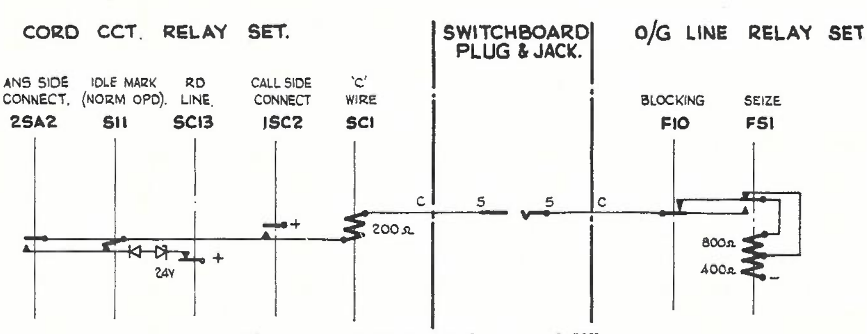


Fig. 1. — Switchboard Control Wire.

* Mr. Scott is Engineer Class 3, Internal Equipment, Queensland. See Vol. 19. No. 1. P. 77.

PICK-UP TIMING.

During the c wire pick-up sequence the following data on line relay set type and signalling requirements must be available in the cord circuit:—

(1) Incoming call or outgoing call.
(2) Register required or not required
(3) Through signalling possible or not possible.
(4) Single pulse ringing or manually controlled ringing.

These conditions are signalled over the speech pair cailhos and d wire during a 175 mS interval between the initial test and the final through connection of the remaining five conductors. Fig. 2 shows the circuit elements used to control the timing.

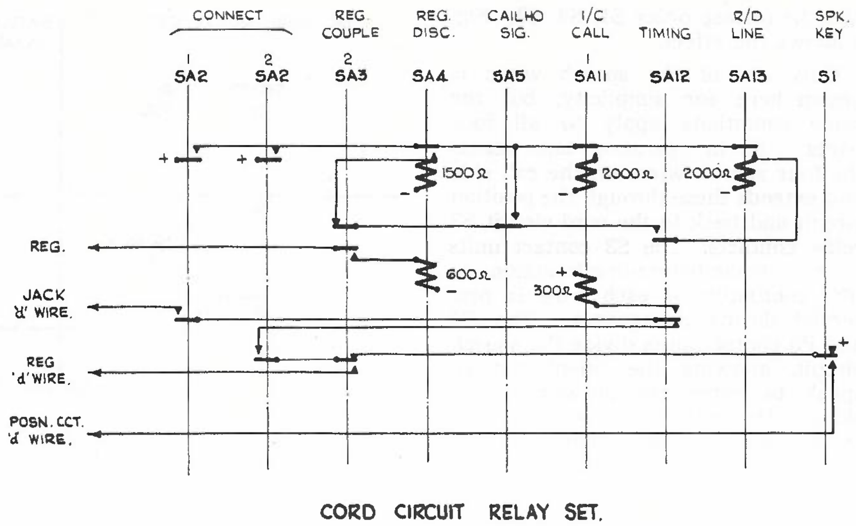


Fig. 3. — Line Relay Set Category Signalling.

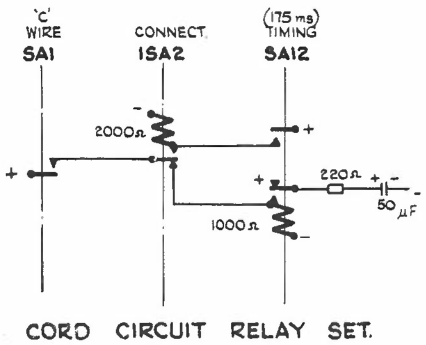


Fig. 2. — Pick-up Timing.

SA1 is the answer side equivalent of SC1 described in Fig. 1 and operates when the answer plug is inserted into the line jack of an incoming L.R.S. SA1 operates SA12, which switches the charged capacitor across its winding and operates 1SA2. 1SA2 opens the operate path of SA12 and holds to SA1. SA12 releases after 175 milliseconds.

In this circuit element the relays are fully sequenced and timing can be maintained within close tolerances using normal adjustment procedures.

LINE RELAY SET CATEGORIES.

The d wire circuit of the answer side of the cord circuit is shown in Fig. 3. When the circuit is idle and before 1SA2 operates, the d wire is open circuit. During pick-up, 1SA2 and SA12 are operated simultaneously for about 175 mS as described above. The d wire is extended to the 300 ohm winding of 1SA11 during this period. 1SA11 will operate to negative battery in the line relay set if the incoming call category is signalled. An outgoing relay set will not apply this signal and absence of the pulse is taken as an indication of an outgoing L.R.S. 1SA11 prepares the cord circuit for a demand type call.

A line relay set connected to a line using manually controlled signalling or code ringing applies an earth to the forward signalling cailho during pick-up. This operates SA5, which operates SA4; and because SA12 is operated, SA13 also operates. SA4 determines that a register is not required and prevents subsequent coupling of a register to the answer side of the cord circuit. SA13 blocks through signalling and prepares a marking condition which is applied to the position circuit relay set when the Speak key is operated. The ringing circuit in the position circuit relay set is modified by this marking signal to provide manually controlled ringing.

When SA12 releases, the operate paths of 1SA11 and SA13 are broken. If normal through signalling is acceptable to the incoming line relay set, it will delay the application of the earth to the forward signalling cailho until SA12 has released. SA12 signals its release to the incoming L.R.S. by applying an earth to the backward signalling cailho. This is acknowledged in the L.R.S. by the connection of earth on the forward signalling cailho which operates SA5. SA5 operates SA4 to prevent register coupling, but because SA12 is unoperated SA13 is not affected.

SA4 operates 2SA2, contacts of which prepare the d wire for switching to the position circuit under the control of S1, and to the register under the control of 2SA3.

SPEECH PATH SWITCHING.

The four wire speech paths are normally through connected from the answer plug to the call plug. No amplifiers or attenuators are included in the cord circuit, but retards and transformers are employed to derive the cailho points for supervision signalling. A speech path crossover occurs to preserve continuity of the directional paths between incoming and outgoing relay sets (or the two outgoing line relay sets on a revertive call). The answer side a1, b1 wires are cross-connected to the call side a2, b2 wires; and the answer side a2, b2 wires connected to the call side a1, b1 wires. A 600-ohm V.F. termination is provided across each speech pair until the answer and call plugs are inserted in line jacks and satisfactory terminations are provided by the line relay sets, or connected lines or channels. S4 operates to disconnect the V.F. terminations usually when the A and B parties commence conversation.

When a cord circuit speak key is pressed, Relays S1-3 switch the four speech wires to the Position Circuit relay set. The through connection in the cord circuit is broken and the answer and call sides are diverted independently to the Position Circuit, where the through condition is preserved via the P4 and P5 relay contacts. The switching by S1-3 must be performed without interrupting the through condition on either speech pair. These relays are sequenced so that the operating order is S1, S2, S3 and the release order S1, S3, S2. Fig. 4 shows the effect.

Only one of the speech wires is drawn here for simplicity, but the same conditions apply to all four wires. S2 in operating taps across the four speech wires on the call side and extends these through the position circuit and back to the cord circuit S3 relay contacts. The S3 contact units have a make-before-break action so that continuity of each wire is preserved during changeover. The P4 and P5 contact units divide the speech circuit, allowing the telephonist to speak to either the answer or call sides. The answer side is terminated in 600 ohms by the position circuit, which also releases S4 in the Cord Circuit to provide a V.F. termination on the call side.

Speak key release causes S3 to restore before S2, thus ensuring that a speech path is established via the cord circuit before the position circuit diversion is fully disconnected at S2.

SPEECH PATH CONTACT WETTING

Each of the two directional speech pairs carries a cailho signalling path. Fig. 5 shows the circuit elements used to derive a d.c. signalling cailho on the forward speech pair between an incoming line relay set and a cord circuit. The direction of signalling over the cailho is opposite to the speech direction. The arrows in the circuit indicate the direction of speech not signalling. Closed circuit d.c. operation is employed on the cailho. Signals consist of 159 mS or 600 mS open circuits. The choice of closed circuit working assists in providing a form of contact wetting.

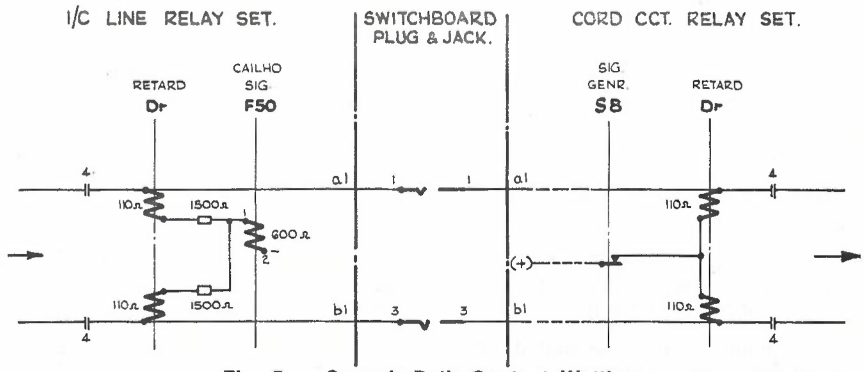


Fig. 5. — Speech Path Contact Wetting.

The design of the speech path circuits is such that series contacts are kept to a minimum. Relay contacts in the series path are shunned, but some contacts such as plug-to-jack are unavoidable. Wetting ensures that these contacts present a low impedance to speech currents. In Fig. 5 approximately 17 mA flow in each speech wire.

To illustrate the application of contact wetting, suppose a high resistance electrical contact is encountered between the plug and jack on wire 3. Now with no current flowing in wire 3, the plug conductor will be at earth potential. The jack conductor will be at the same potential as that present on the No. 1 tag of the F50 relay, i.e., approximately 37 volts. Thus a potential of 37 volts is applied to the fault, which if due to a film of oxidised material, will break down and allow conduction. The normal 17 mA current will ensure that conductivity is maintained.

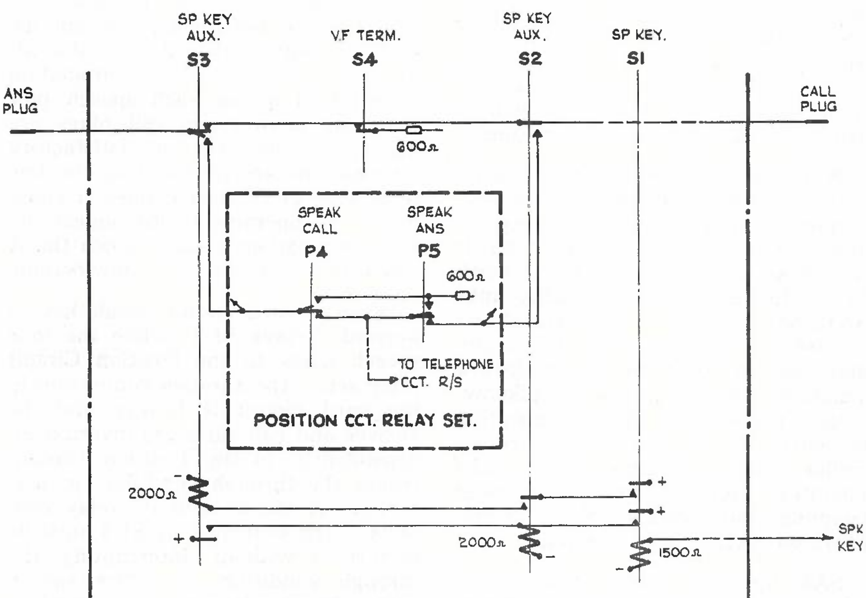
The ohmic resistance values of the components are selected for optimum voltage distribution. The 110-ohm retard windings offer a low resistance path for cailho d.c. signals, but present a high impedance bridge across the speech pairs. The 1500-ohm resistors and the 600-ohm F50 relay coil limit the total circuit current and provide the highest possible wetting voltage to a defective connection.

BACKWARD SIGNAL RECEPTION AND REPETITION.

On a demand call from one C.B. or automatic telephone to another, backward supervisory signals from the B party are repeated by the cord circuit to the A party. The signals are received on the call side, timed and stored, then regenerated on the answer side. SC5 is the cailho relay on the call side and is normally operated during a call as explained above. Answer signal from the B party consists of a 150 mS open circuit in the backward cailho. Fig. 6 shows the circuit elements involved for backward signals.

When the call side of the cord circuit is connected, SC5 operates and charges the capacitor associated with the SC7 relay. SC5 releases at the commencement of a backward supervisory signal causing SC7 to operate from the discharge current provided by the capacitor. If SC5 re-operates within 300 mS, SC7 will still be held to the capacitor discharge and becomes locked to the earth at SC5 via its own contact unit. If the signal lasts for 600 mS, the capacitor dissipates its charge and SC7 restores. Thus SC7 discriminates between short and long signals.

At the re-operation of SC5 following receipt of an answer signal, SC7 will be held and a path is provided to operate S7. S7 pulse operates S8 for 150 mS on its 300-ohm winding and contacts of S8 interrupt the an-



CORD CIRCUIT RELAY SET.
Fig. 4. — Speech Path Switching.

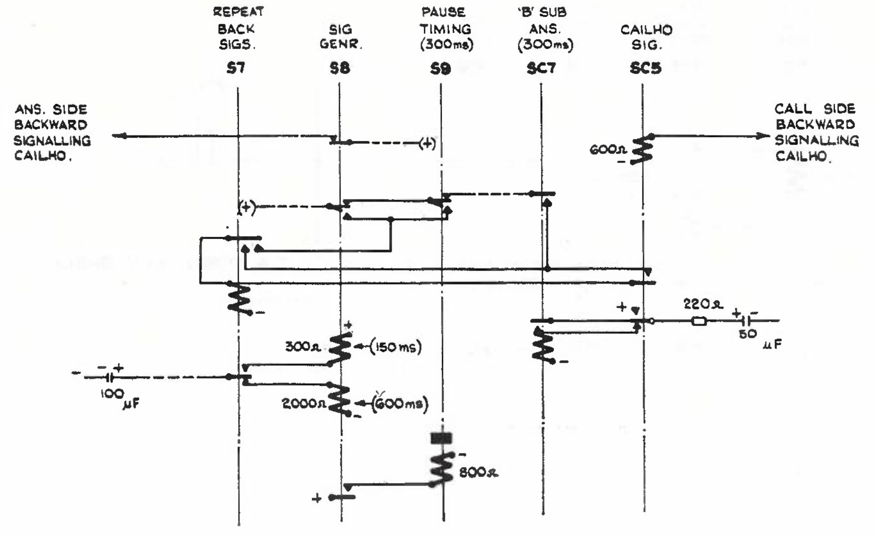


Fig. 6. — Backward Signal Reception and Repetition.

swer side backward cailho signalling path for this duration. S8 also locks S7 to prevent its release until the full answer signal pulse has been sent, and operates S9, which provides a further hold on S7 to ensure that a follow-on backward signal cannot be transmitted until 300 mS has elapsed after the previous signal. When S8 and S9 release, S7 is again under the control of SC5 and SC7.

A clear back signal from the B party will release SC5 for this period. SC7 will release after 300 mS causing S7 to release. S7 pulse operates S8 for 600 mS on its 2000 ohm winding and contacts of S8 repeat the signal on the answer side cailho. Contact units of S8 and S9 prevent the re-operation of S7 until the clear back signal is sent and a pause of 300 mS is timed.

The lock-on and lock-off circuits provided by S8 and S9 ensure that backward signals are transmitted for their full duration and that adequate separation between follow-on signals exists to keep supervisory signals at the A and B subscribers' exchanges synchronised.

TIMER CONTROL CIRCUIT.

The connection of the call timer is under the control of the Timer Start key and the relay logic of the cord circuit relay set. It will function under three separate conditions:—

(i) On a normal demand or revertive call when both A and B parties are present;

(b) When the cord circuit is idle, and the timer is used to time a call on another cord circuit giving inadequate supervision;

(iii) When the cord circuit is idle, and the Timer Routine Test key is operated.

Fig. 7 shows the circuit elements involved.

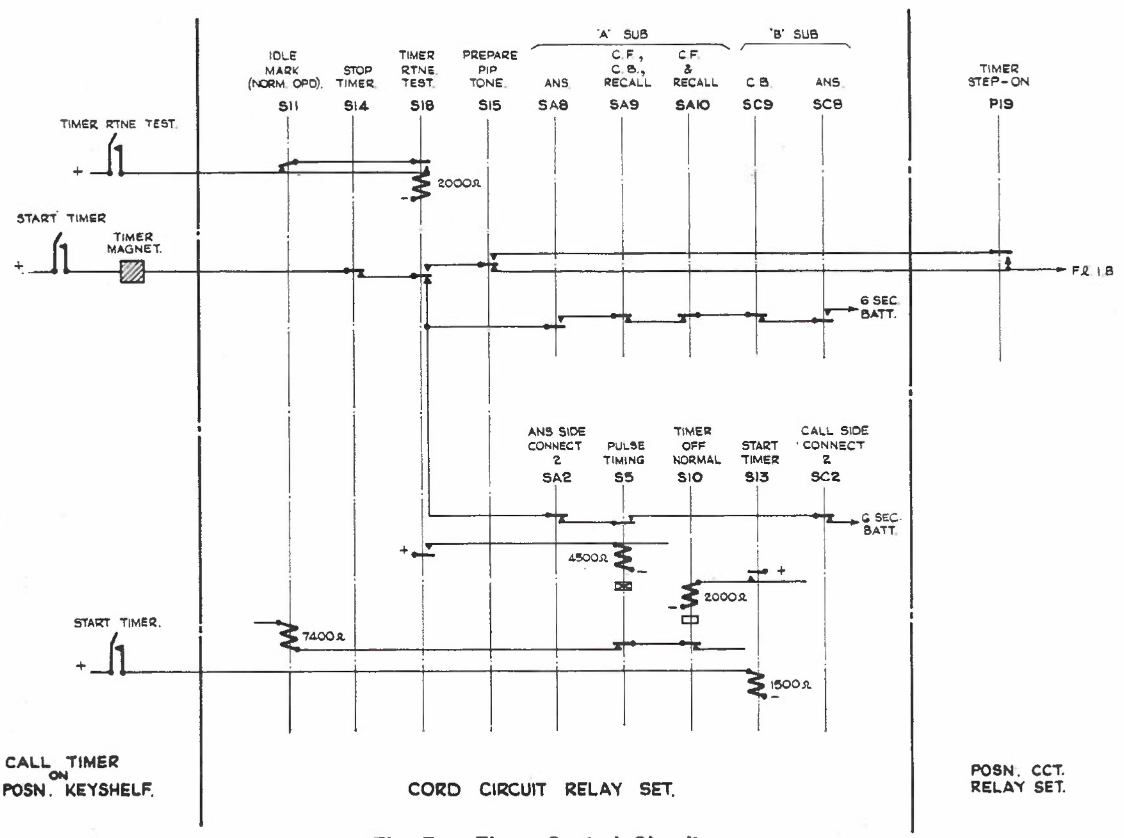


Fig. 7. — Timer Control Circuit.

In the normal case, the Timer Start key prepares the magnet circuit, depending upon the operation of SA8 and SC8, and the non-operation of SA9, SA10 and SC9. SA8 and SC8 correspond to receipt of initial answer signal on the answer and call sides respectively. The Timer Start key may be operated in advance of answer supervision, but the timer will not step until SA8 and SC8 have operated. Clearing of either party will stop the timer. SA9 responds to clear forward or clear back signals on the answer side, and SC9 to clear back on the call side. SA10 operates on receipt of a recall signal and remains held until the Speak key is operated and released.

An alternative operating path for the timer is available when the cord circuit is not in use, i.e., when relays 2SA2 and 2SC2 are unoperated. Operation of the Start key will cause the timer to step immediately. S13 operates in the usual way, followed by S10. S10 releases the idle mark relay S11, which prevents the cord circuit being used for traffic.

An inbuilt routine test circuit is provided. Operation of the Timer Routine Test key operates relay S18 if the cord circuit is idle marked by S11. S18 operates S5 and S5 releases S11 to prevent the cord circuit being used for traffic. S18 connects FL.1 battery (0.2 secs. ON, 0.2 secs. OFF) in place of the normal 6 seconds supply, causing the timer to step rapidly to the 2.8 minute setting when S15 operates. The telephonist may now listen to continuous 3-pip tone signals by pressing either the Speak or Monitor keys. If the timer start key is operated in the Coin Telephone position, the timer supervisory lamp will flash. After checking that all timer functions are satisfactory at the 2.8 setting, the telephonist may press the Timer Step On key, which operates P19 and provides an alternative operating path for the timer magnet. As the timer steps, S15 will restore, returning the magnet to the initial operating path for stepping to continue to the 5.8 minute setting where the previous tests and indications are repeated. Further pressing of the Timer Step On key will advance the timer to the 8.8 minute setting. If pressed again, the timer will step to the 9.0 minute setting, which is the limit of its reading. S14 will operate and disconnect the magnet. The Timer Supervisory lamp will flash.

A circuit safeguard prevents the timer being inadvertently or deliberately switched to the rapid stepping pulse lead when the cord circuit is engaged on a legitimate call. As soon as either plug is taken into use to handle a call, the connect relays 2SA2 or 2SC2 break the circuit of S11 causing it to release. S11 prevents the operation of S18, which controls the fast stepping pulse. S11 will not re-operate until the cord circuit is restored to normal and the timer is reset to the 9.9 minute position.

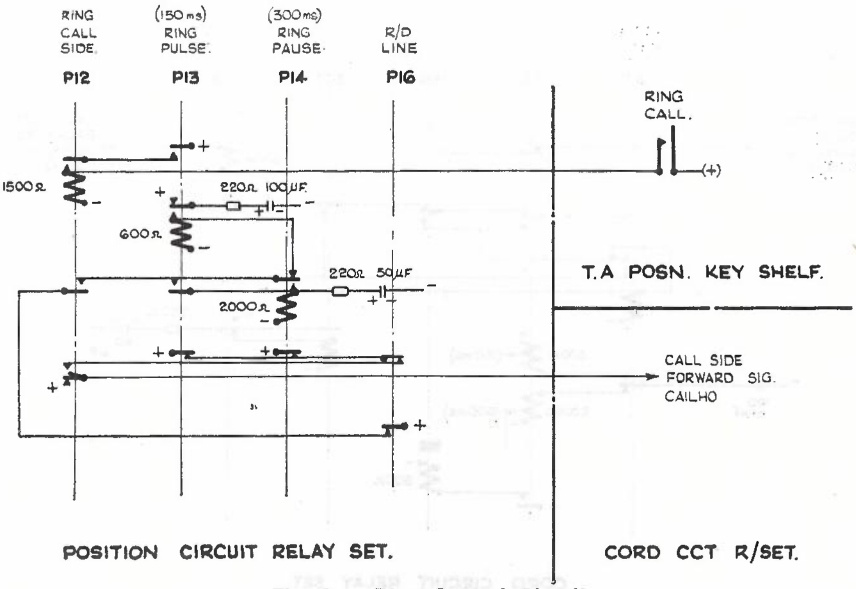


Fig. 8. — Ring Control Circuit.

RING CONTROL CIRCUIT.

A ring from the switchboard to a line relay set consists of an interruption to the forward cailho signalling path. The ringing signals originate from the position circuit relay set under the control of the keyshelf ring call and ring answer keys. When the telephonist presses a Speak key, the two cailho paths are diverted to the position circuit relay set. Fig. 8 shows the circuit elements involved on the call side of the position circuit.

The Ring Call key operates P12, and providing that a ring down line mark is not current to operate P16, P12 operates P13; P13 operates P14; P14 disconnects P13 but leaves it with a charged capacitor connected across its winding. The open circuit on the signalling cailho commences when P14 operates and extends for the release time of P13 which is 150 mS. P12 is locked by P13 for this period to ensure that a short signal will not result due to the Ring Call key being operated for less than 150 mS. When the Ring Call key is released, P12 will restore and P14 is disconnected, but will remain held for a further 300 mS due to the parallel charged capacitor. P14 times a pause to ensure that a follow-on ring signal cannot occur within 300 mS of the previous one. Should the Ring Call key be repressed during this period, earth from the P16 contact unit will hold P14 rather than operate P13. On the release of P14 the circuit is restored to normal.

If the call side of the cord circuit is connected to a line relay set requiring manual controlled ring signals, a ring down mark will be stored on relay SC13. When the Speak Key is operated, this mark is transferred to the position circuit where P16 operates. P16 prevents P13 and P14 operating. Pressing of the Ring Call key operates P12, which opens the cailho signalling lead. The length of signal transmitted depends entirely on the time that the Ring Call key is pressed. This permits sending ring signals of long duration and code ringing.

CALL MONITOR REMINDER GONG.

Each Trunk Assistance and Special Services position is equipped with a Call Monitor key, which is used by the telephonist to call for the monitor's attention. A Call Monitor lamp lights on the calling position. A pilot lamp and an individual position lamp light on the Monitor's turret.

Fig. 9 shows the circuit elements involved in the Monitor's position circuit for the connection of an audible gong. When the Call Monitor key on a T.A. position is pressed P21 in the position circuit operates, which subsequently operates P8 in the Monitor's position circuit. P8 switches a charged capacitor to the monitor's gong, which operates during the discharge of the

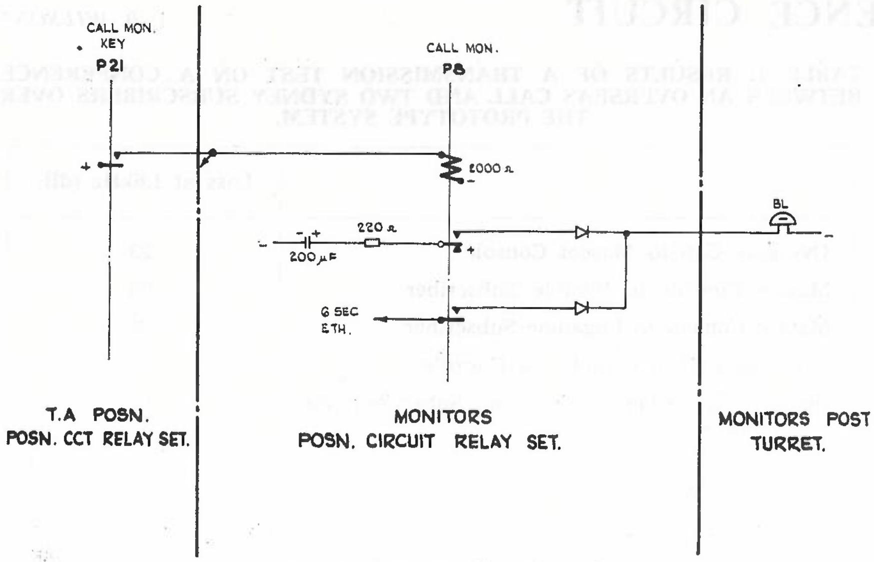


Fig. 9. — Call Monitor Reminder Gong

capacitor. P8 also connects a 6 second pulse lead to the gong so that a reminder is given every 6 seconds until the call is acknowledged.

CONCLUSION

The circuit elements described in this article form the basis of the Trunk Assistance position circuit design. Some of the elements occur in many of the line relay sets while others find application in the Special Services Position circuits. These are the building blocks of System AFM402.

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1.—F. M. Scott, 'System AFM402— The A.P.O. Four Wire Cord Type Manual Assistance Centre'; Part 1, Telecom Journal of Aust., Feb. 1969, Vol. 19, No. 1, p. 41; Part 2, Telecom. Journal of Aust., June 1969, Vol. 19, No. 2, p. 136.

TECHNICAL NEWS ITEM

JOINT CONFERENCE OF THE AUSTRALIAN POST OFFICE AND THE ELECTRICITY SUPPLY ASSOCIATION OF AUSTRALIA

A joint conference between the Australian Post Office and the Electricity Supply Association of Australia was held in Melbourne in April of this year, to discuss the co-ordination of power and telecommunication systems.

Since 1953, regular conferences on current problems have been held, and Joint Committees for the Co-ordination of Power and Telecommunication Systems operate in each State. A Central Joint Committee with headquarters in Melbourne, advises and co-ordinates the work of the State Joint Committees.

The 1969 conference reviewed the progress made since 1965 in the preparation and/or revision of the jointly-agreed Codes of Practice on which co-ordination practices are based, and set further targets for the Central Joint Committee.

Current projects include long-term investigations into the severity and the frequency of occurrence of power line earth faults to provide factual background material for Codes of Practice on 50 Hz voltages induced into telecommunication lines during power line earth faults, and potential rise of power earth mats during power earth faults. The revision of the present Conditions for Single Wire Earth Return H.V. Power Lines is proceeding, and the need for an investigation into a Code of Practice on the use of Tone Injection Control Systems on power lines is being evaluated. The feasibility of joint-use underground construction between power and telecommunications plant has been assessed and further investigatory work is proceeding towards the preparation of an arrangement of installation and maintenance practices.

A SPECIAL CONFERENCE CIRCUIT

*A. B. WILSON**

INTRODUCTION.

If, in the conduct of International Aircraft Operations, it became necessary to delay the departure of an aircraft for a period in excess of its normal transit time, then management is faced with extra tasks such as rearranging flight schedules, bookings and procuring aircraft spare parts, etc., this work is further complicated if the aircraft happens to be grounded at an overseas airport, when the discussions have to be conducted over the International Communications System.

To facilitate these operations, Qantas established a Flight Control Centre at Mascot Airport, Sydney, and applied for two press-button operated consoles with the following facilities:—

(a) one exchange line with STD access;

(b) four P.A.B.X. extension lines;

(c) sixteen C.B. extension lines;

(d) the ability to establish a conference between an overseas line and a selected combination of exchange lines, P.A.B.X. and and C.B. extension lines.

The switching together of exchange lines is not usually permitted in the Australian Post Office, but because of the importance of the facility in the conduct of international flying operations, the arrangement was given special approval by the Director-General subject to the following conditions:—

(i) the design of all units had to be approved by the P.M.G. Department.

(ii) Conference facilities had to be restricted to six parties at any one time.

(iii) Transmission had to be held within the limits imposed by the Metropolitan Transmission Plan.

TRANSMISSION LIMITS

The maximum permissible loss subscriber to subscriber is approximately 33dB at 1.6kHz and consideration had to be given to the overall loss that would be encountered over all the possible switching patterns. Conferences could be required between:

(i) an overseas caller and a combination of P.A.B.X. and C.B. extensions at Mascot;

(ii) an overseas caller and a combination of P.A.B.X. and C.B. extensions and a number of exchange lines to home addresses.

(iii) an overseas caller and up to four exchange lines to home addresses. To aid in these investigations, Qantas submitted the names of fifteen officials who could be called into a conference, the home addresses of these people being as far apart as Pymble (a northern suburb), Blakehurst and Engadine (both southern suburbs).

It was considered that no problems would be encountered with the type (i) conference and subsequent transmission tests confirmed this opinion.

As the type (ii) and (iii) conferences involved more than one exchange line, transmission difficulties were anticipated.

TABLE 1: RESULTS OF A TRANSMISSION TEST ON A CONFERENCE BETWEEN AN OVERSEAS CALL AND TWO SYDNEY SUBSCRIBERS OVER THE PROTOTYPE SYSTEM.

	Loss at 1.6kHz (dB)
Overseas Call to Mascot Console	23
Mascot Console to Pymble Subscriber	26
Mascot Console to Engadine Subscriber	26
Overseas Call to Pymble via Console	57
Pymble Subscriber to Engadine Subscriber via Console	60

Table 1 shows the results of a hypothetical conference established between an overseas caller and two Sydney subscribers, one at Pymble, the other at Engadine; it was assumed that an 8dB loss would be introduced at the control console.

From these results, it was obvious that an effective conference could not be established through the Console.

The possibility of the Overseas Exchange Operator controlling the conference was then considered, the home telephones being called in and cross-switched at that point. This suggestion was not practicable because the Qantas Flight Controller had the responsibility of deciding who would be the parties to a particular conference. After further consideration of the operational problems and further field investigations, it was finally decided that a Remote Control System aided by four-wire amplification would be adopted.

Table 2 shows the results of an overall transmission test on the final system and a useful comparison can here be made with Table 1.

TABLE 2: RESULTS OF A TRANSMISSION TEST ON A CONFERENCE BETWEEN AN OVERSEAS CALL AND TWO SYDNEY SUBSCRIBERS OVER THE FINAL SYSTEM.

	Loss at 1.6kHz (dB)
Overseas Call to Mascot Console	17
Mascot Console to Pymble Subscriber	26
Mascot Console to Engadine Subscriber	26
Overseas Call to Pymble Subscriber via City South	28
Pymble Subscriber to Engadine Subscriber via City South	29

* Mr. Wilson is Engineer Class 2, PABX Installation, N.S.W.

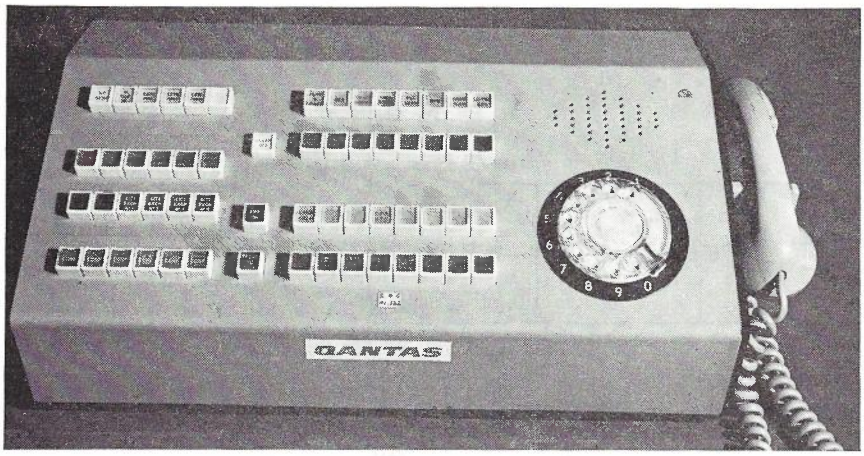

Fig. 1. — Conference Console.

Details of the Remote Control Circuit appear later in this article.

RESTRICTION OF CONFERENCE PARTICIPANTS TO SIX.

A magnetic locking press button key was used to restrict conference parties to six. Referring to Fig. 1 and Fig. 2, it can be seen that the operation of any Conference or C.B. extension key places a 10,000 ohm resistor R1 in parallel with a 15,000 ohm resistor R2, the resistor R2 forms part of a transistor switching circuit.

Earth is provided to the key magnetic circuits via the operated springs of HV relay (normally held operated).

If it is attempted to set up a conference of seven parties, then the joint resistance of R2 and the seven R1 resistors is reduced to 1304 ohms, causing equal and opposing currents to flow in the windings of HV relay, which now releases and in turn causes the release of the seven conference keys; up to six keys will remain operated in conference.

CONFERENCE REMOTE CONTROL CIRCUIT

A City South bothway exchange line fitted with four-wire amplification and a special final selector relay set was listed for overseas calls.

Four OUT lines from the Mascot Console consisting of two cable pairs per circuit were terminated in group selectors at City South with a special

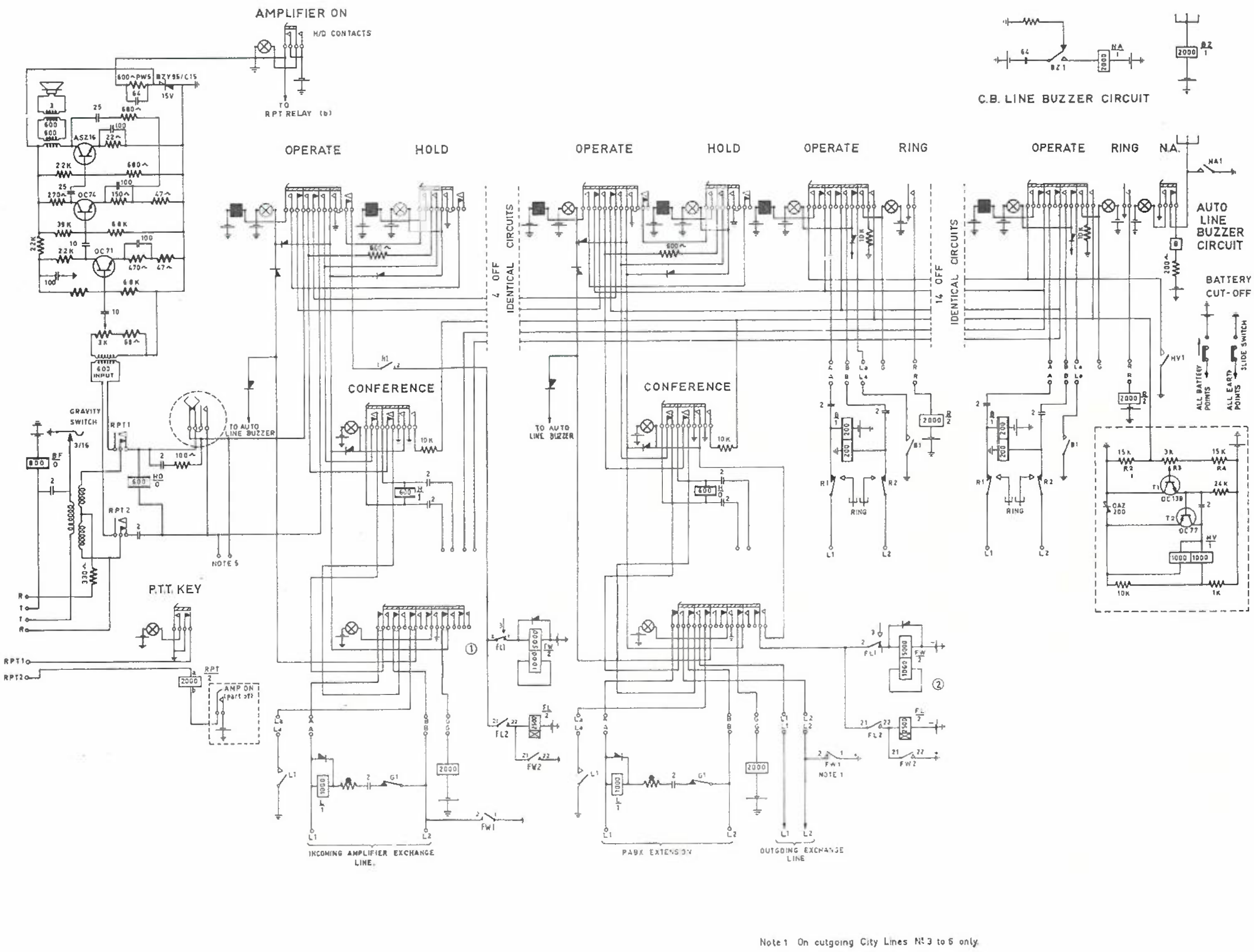

Fig. 2. — Conference Console Circuit.

WILSON — Conference Circuit

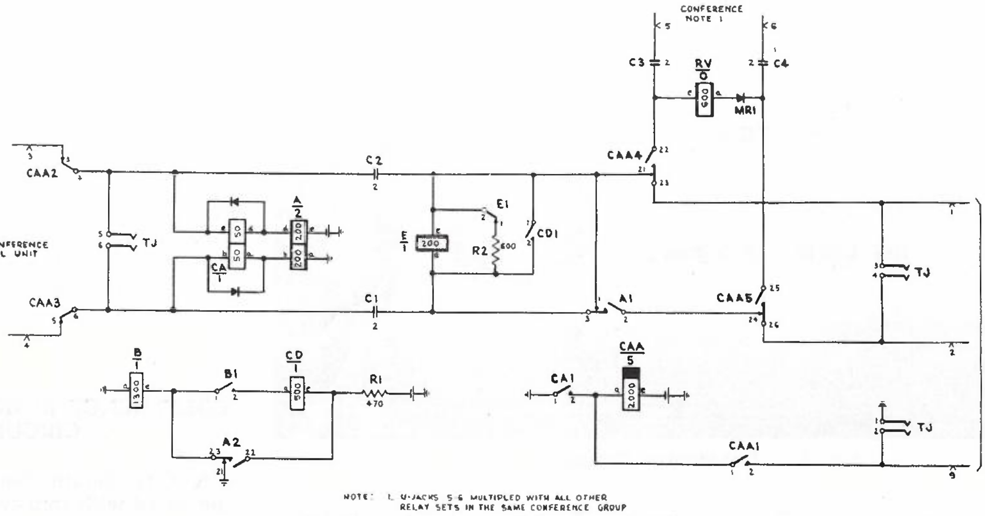

Fig. 3. — Group Selector Relay Set.

group selector relay set (Fig. 3) inserted between each group selector and the Mascot Console. Four auxiliary keys were fitted to the Console so that the operator could call public exchange numbers over these group selectors for conference purposes.

GROUP SELECTOR AND FINAL SELECTOR RELAY SETS

An overseas call is extended to the Console via the Final Selector Relay Set (Fig. 4), a.c. ring from the Final Selector operates Relay L, contacts L1-2 operate Relay LB and a.c. ring is repeated out to the Console. When the Operator answers, relay A operates and operates relay B via A1-2. B23-24 in conjunction with retard RO trips the ring and the overseas call is connected through to the Mascot operator.

Should a Qantas official be required in conference from his home address, the operator holds the overseas call via the hold key, then depresses a P.A.B.X. line key and the associated auxiliary key and so loops the Group Selector at City South via the operated contacts of relay A in the Group Selector relay set (Fig. 3). A22-23 initiates the operation of relays B and CD.

Standard short circuit dialling conditions are provided via CD relay contacts and the 600 ohm resistor R1.

The operator can call any combination of C.B., P.A.B.X. or exchange lines up to a maximum of six—the individual hold keys being operated in each instance. C.B. lines being fitted with a single call and answer key, are automatically in conference when this key is operated. When all required connections have been established, the individual Conference Keys are now operated and momentarily a short earth pulse is applied to:—

(a) the overseas call, which operates CA relay in the Final Selector Relay Set. CA 1-2 contacts operate relay CAA and the contacts of CAA switch the overseas line to a common connection at City South and also directly through to the Mascot Console.

(b) the home address exchange line which operates relay CA in the Group Selector relay set. CA1-2 contacts operate CAA relay and CAA contacts switch the line to the common connection and also release the City South to Mascot portion of the line, the connection being held at City South by RV retard and rectifier MR1, the circuit now

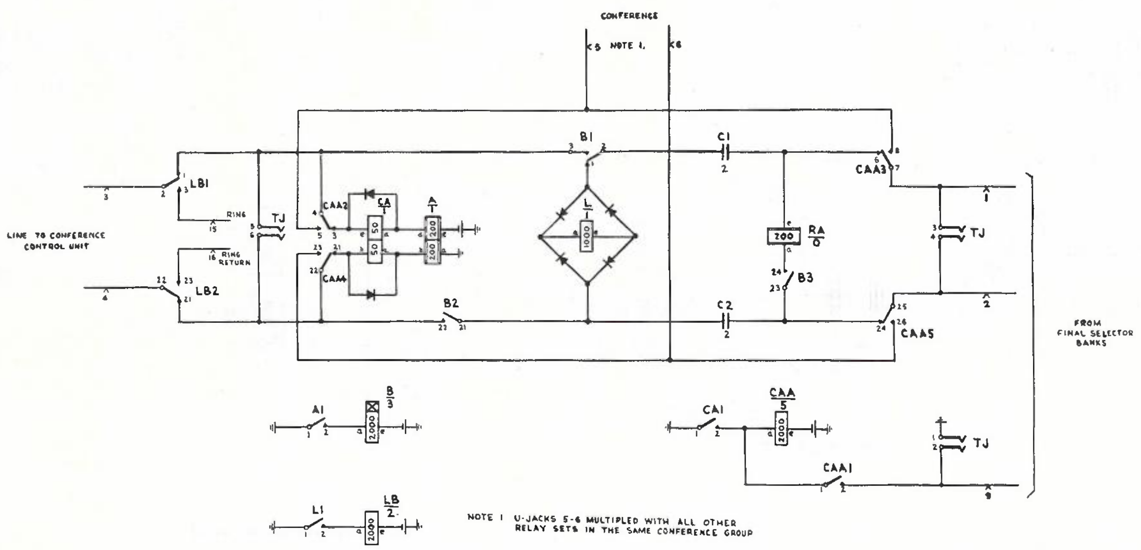

Fig. 4 — Final Selector Relay Set.

being under the control of the called official at his home address (Reversal Hold Conditions).

Local P.A.B.X. or C.B. extensions at Mascot are brought into this type of conference via the City South-Mascot portion of the overseas line.

THE SWITCHING CONSOLES.

Qantas specified a plastic top of table console of the type made by E. S. Rubin and Co. Pty. Ltd., with rack-mounted relay equipment and plug and socket terminated consoles.

From Fig. 1 and Fig 2 it can be seen that N.S.W. standard non-switching unit circuitry has been utilised and differs only in the provision of:

(a) A conference key per circuit (6 off).
(b) Auxiliary keys that enable the operator to select either P.A.B.X. lines or exchange lines (this procedure is adopted when exchange lines are included in the conference).
(c) A transistor circuit to ensure that conference parties are restricted to six.
(d) A receive amplifier associated with the operator's circuit.
(e) An earth pulse circuit (utilised in setting up a conference involving exchange lines).

Fig. 5 shows the Mascot Flight Control Centre, the relay sets for the Consoles being installed in the cabinet in the centre front of the figure.

CONCLUSION

The Qantas Conference Circuit has now been in service for 12 months— is being used frequently, and is proving to be of estimable value in maintaining flght schedules.

ACKNOWLEDGEMENT

The successful development of this facility was due in large measure to the staff of P.A.B.X. Installation No. 2, Sydney, and of E. S. Rubin and Co. Pty. Ltd.

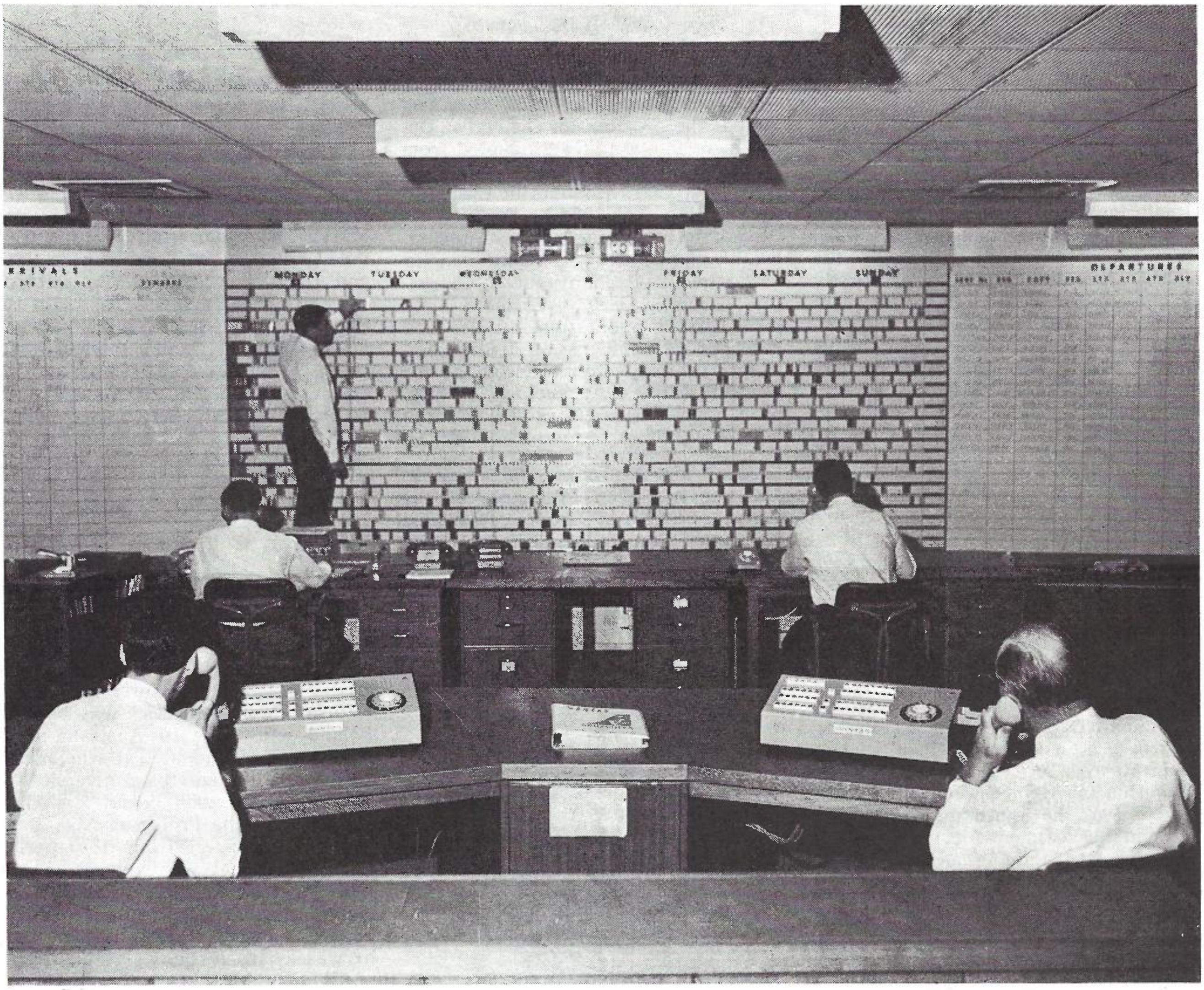

Fig. 5. — Mascot Flight Control Centre.

OUR CONTRIBUTORS

G. P. KIDD

J. E. SANDER

J. L. PARAPAK

G. P. KIDD, author of 'Mathematics of Reliability,' studied at the University of Queensland as a Cadet Engineer, graduating a Bachelor of Engineering in 1961. He subsequently obtained a Bachelor of Science (majoring in statistics) from the University of Melbourne in 1966. Since 1962 he has been with the P.M.G. Research Laboratories, firstly in the Laboratory Equipment Division, then from 1965 to 1968 with the Probability Division, and presently as acting Divisional Engineer of the Transmission Lines Division. He is a member of the Statistical Society of Australia.

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J. E. SANDER, author of the article 'Numerical Design of Relay Circuits,' joined the Postmaster-General's Department in 1943. He graduated from the University of Western Australia with First Class Honours in Electrical Engineering. In 1964 he travelled to Stockholm, Sweden, as a Commonwealth Public Service Board scholar and studied telephone switching system design with L.M. Ericsson. He also carried out formal studies and research into the use of digital computers in relay circuit design at the Royal Institute of Technology (K.T.H.), Stockholm. This work led to the degree of Telnisk Licentiat from K.T.H.

Since his return to Melbourne in 1966 he has been in charge of the Circuit Standards Group, Telephone Exchange Equipment Section, Headquarters.

★

J. L. PARAPAK, author of the article, 'The Introduction of Electronic Devices into Electromechanical Telephone Equipment,' arrived in Australia from Indonesia in 1962 as a Colombo Plan scholar. He obtained the Degrees of Bachelor of Engineering and Master of Engineering Science from the University of Tasmania in 1966 and 1969 respectively. Mr. Parapak worked as an Engineer Class 1 in the Radiocommunications and Broadcasting Division of the Postmaster-General's Department in Hobart during 1968 and 1969, and is currently attached to Headquarters Radio Section.

★

Y. F. TONG, author of the article, 'Optimum Design of Tapered Busbar Systems', is a Colombo Plan student from Malaysia. After graduating as B.E. with Honours from Queensland University in 1967, he joined the Postmaster-General's Department for 12 months to gain practical training and experience in telecommunications.

During that period he was attached to the Country Equipment Installation section, Qld. On completion of the 12 months training period, he will be proceeding to Monash University to do postgraduate studies in communication theory on a Monash Graduate Scholarship.

Mr. Tong is a member of the Institute of Electrical and Electronic Engineers.

Y. F. TONG

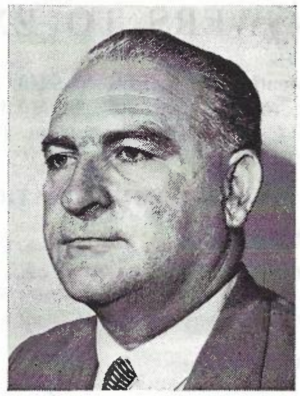
R. WIELEBINSKI, author of the article 'Antenna Measurements Using Natural Radio Sources,' was born in Poland and came to Australia as a child. He graduated Bachelor of Engineering from the University of Tasmania in 1958 with first-class honours and the Professor Alan Burn Faculty Prize. During the period 1958-60 he was an engineer in the P.M.G.'s Department and was responsible for the construction of the Hobart T.V. transmitter ABT2. In 1960 he was awarded the degree of Master of Engineering Science and in the same year won a Shell Post-graduate scholarship, which allowed him to study radio-astronomy at the Cavendish Laboratory, Cambridge, under Professor (now Sir Martin) Ryle; in 1963 he received the degree of Doctor of Philosophy.

R. WIELEBINSKI

Mr. Wielebinski joined the staff of the Electrical Engineering School, the University of Sydney, at the end of 1963 as Lecturer and became Senior Lecturer in January, 1966. In 1970 he will take up appointment as a Director of the Max-Planck-Instut fur Aadio-Astronomie, Germany, where a 100 m. fully steerable antenna is under construction.

★

A. B. WILSON, author of the article 'A Special Conference Circuit,' joined the Department in Sydney in 1945 as Technician's Assistant and qualified as Technician and Senior Technician in 1952. He was engaged in Exchange and Substation maintenance until 1955, when he became a Technical Instructor Grade 2. He qualified as Engineer in 1956 and has worked as Engineer Class 2 in Metropolitan Service and Substation Installation Divisions.



A. B. WILSON

Since 1961 he has been in P.A.B.X. Installation and has been specially concerned with the problems of block wiring of large office buildings, the installation of P.A.B.X.'s, non-switching units and other special subscribers' facilities.

TECHNICAL NEWS ITEM

INTRODUCTION OF MOISTURE BARRIER CABLE SHEATHS

Since the first general introduction of telecommunication cables, lead has been the traditional sheathing material for paper insulated cables. While it has given satisfactory service, its cost, weight and susceptibility to fatigue when transported, have directed attention to alternative materials.

During the last World War a light-weight steel sheath with an outer polythene jacket was developed in the U.S.A. and also in Europe.

In recent years the British Post Office has introduced a light-weight moisture-proof sheath consisting of an aluminium foil bonded to the underside of a polythene sheath for use with paper insulated cables.

The aluminium foil effectively prevents the permeation of water vapour through the polythene while the characteristics of the polythene make it a suitable sheathing material.

This cable sheath is now being generally introduced into the Australian Post Office as a substitute for lead on large cables installed in conduits after extended trials of both imported and locally manufactured cable.

It will reduce cable costs and simplify transportation and installation because of its light weight. Its excellent corrosion resistant properties will remove the hazards of corrosion particularly in the presence of stray electrolytic currents in city areas.

ANSWERS TO EXAMINATION QUESTIONS

Examinations Nos. 5931 to 5940, 5 July 1969 and subsequent dates; to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Postmaster-General's Department.

TELECOMMUNICATION PRINCIPLES

QUESTION 1 (a):

Four resistors are designated R1, R2, R3 and R4. The resistance of R2 is one-fifth of R1, R3 is x times R2, and R4 is 10y times R3. If Z ohms represents resistor R1, what will represent the other three?

ANSWER 1 (a):

$$R2 = \frac{Z}{5}\text{ ohms}$$

$$R3 = \frac{xZ}{5}\text{ ohms}$$

$$R4 = 2xyZ\text{ ohms.}$$

QUESTION 1 (b):

A battery of E volts is connected across a resistor of R ohms and a power P_1 is dissipated in the resistor. When the voltage is reduced to x% and the resistor is increased to y times its original value, P_2 watts are dissipated.

(i) State the new values of E and R when P_2 watts are dissipated.

(ii) State the formulae for P_1 and P_2 in terms of the values of E and R.

(iii) Write an expression for the PERCENTAGE CHANGE in the dissipated power in terms of P_1 and P_2; and then substitute the values for P_1 and P_2 from (ii) above and express the result in the simplest form.

ANSWER 1 (b):

(i) E becomes $\frac{xE}{100}$

R becomes yR

(ii) $P_1 = \frac{E^2}{R}$; $P_2 = \frac{x^2E^2}{(100)^2} \times \frac{1}{yR} = \frac{x^2E^2}{(100)^2yR}$

(iii) Percentage change $= \left(\frac{P_1 - P_2}{P_1}\right) \times 100 = \left(1 - \frac{P_2}{P_1}\right) \times 100$

$$= \left(1 - \frac{x^2E^2}{(100^2)yR} \times \frac{R}{E^2}\right) \times 100$$

$$= 100\left(1 - \frac{x^2}{(100)^2y}\right)$$

$$= 100 - \frac{x^2}{100y}.$$

QUESTION 2 (a):

In the circuit drawing (Fig. 1), the capacitor is fully discharged when contacts AA are closed. The magnetic flux densities produced by the coils of the differentially wound relay K are indicated as $\phi 1$ and $\phi 2$. Describe the basic principles of the operation of relay K.

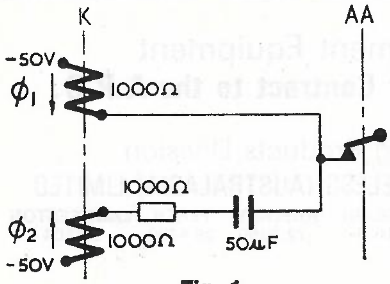


Fig. 1

ANSWER 2 (a):

Immediately contacts AA are closed, current flows in both coils of K. The flux (ϕ_1) developed in the upper winding is opposed by the flux (ϕ_2) developed by the capacitor charging current in the lower winding (the relay being differentially wound). As the capacitor charges, the potential across the plates builds up and opposes the applied potential, so reducing the current and flux (ϕ_2) in the lower winding. After a time delay, the difference between the values of flux in each winding ($\phi_1 - \phi_2$) is such that the resultant flux operates the relay. The relay therefore has a timed operation lag.

QUESTION 2 (b):

In the circuit (Fig. 2) a time delay is introduced in the operation of the relay. The switch rests in position 1 and timing starts when the switch is operated to position 2. The relay operates when the grid potential is –10 volts and releases when the grid potential is –15 volts, with respect to the cathode in each case. Calculate the value of the capacitor to give a 4.6 minute delay.

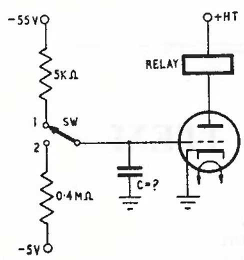


Fig. 2 (a)

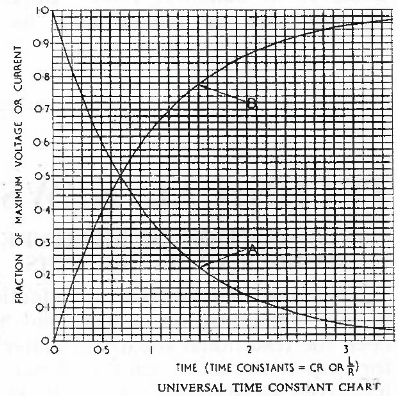


Fig. 2 (b)

ANSWER 2 (b):

Initially C is charged to –55 volts. The relay operates when the grid is at –10 volts, that is, when the capacitor has discharged from –55 to –10 volts. In the circuit (Fig. 2a), however, when the switch is moved to position 2 it connects the capacitor and the grid to a potential of –5 volts. As shown in Fig. 3 this has two effects on the grid in relation to the operation of the relay:—

(i) The total voltage charge of the capacitor is 50 volts.

(ii) The relay operates when the capacitor has discharged to –10 volts and capacitor voltage is reduced by 45 volts i.e. the valve conducts and operates the relay when the capacitor has discharged to 10% of its relative initial voltage.

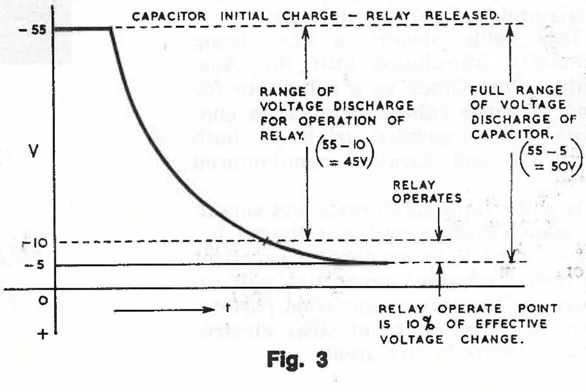


Fig. 3

From the time constant chart (Fig. 2b), curve A, 10% corresponds to 2.3 circuit time constants. Therefore 2.3 time constants = 4.6 minutes.

$$TC = \frac{4.6}{2.3} = 2 \text{ minutes} = 120 \text{ seconds}$$

$$C = \frac{TC}{R} = \frac{120 \times 10^6}{4 \times 10^5} = 300\mu F$$

Examiner's Note:—
Some candidates used the charge curve (curve B) of the Universal Time Constant Chart. As the question was dealing with the discharge curve (curve A) no marks were awarded to these candidates although in a few cases an apparently correct answer was obtained.

QUESTION 3 (a):

Solve the equations for x:—

(i) $5(x - a) - 3(x + a) = 2$.

(ii) $\log(10 + 8x) = 1 + \log 5$.

(iii) $(9x - 16a)^2 = 4a^2$.

ANSWER 3 (a):

(i) Removing brackets:—

$$\begin{aligned} 5x - 5a - 3x - 3a &= 2 \\ 2x - 8a &= 2 \\ 2x &= 8a + 2 \\ x &= 4a + 1 \end{aligned}$$

(ii)

$$\begin{aligned} \log(10 + 8x) &= \log 10 + \log 5 \\ &= \log(10 \times 5) \\ &= \log 50 \\ 10 + 8x &= 50 \\ 8x &= 40 \\ x &= 5 \end{aligned}$$

(iii) Taking the square root of both sides of the equation:

$$\begin{aligned} 9x - 16a &= \pm 2a \\ 9x &= 18a \\ x &= 2a \end{aligned}$$

(The answer for —2a was not required, but gives $X = 1\frac{5}{9}a$)

QUESTION 3 (b):

Express:

(i) In polar form, the impedance Z of a circuit which is purely inductive and $X_L = 7\Omega$.

(ii) $\log \frac{B}{10A}$ *in terms of log A and log B.*

(iii) 77° in radians (use $\pi = 22/7$*).*

(iv) the decimal number 147 as a binary number.

(v) y in terms of x and z when given that $\text{antilog}\left(\frac{xy}{z}\right) = 100$.

ANSWER 3 (b):

(i) $Z = 7\angle 90°\Omega$.

(ii) $\log B - \log 10A = \log B - (\log A + \log 10)$.
$= \log B - \log A - 1$

(iii) π radians = 180°.

$$77° = \frac{22}{7} \times \frac{77}{180} = \frac{121}{90} = 1.34 \text{ radians}$$

(iv)

$$\begin{aligned} 147 &= 128 + 16 + 2 + 1 \\ &= 2^7 \times 1 + 2^6 \times 0 + 2^5 \times 0 + 2^4 \times 1 + 2^3 \times 0 \\ &\quad + 2^2 \times 0 + 2^1 \times 1 + 2^0 \times 1 \\ &= 10010011 \end{aligned}$$

(v)

$$\frac{xy}{z} = \log 100 = 2$$

$$y = \frac{2z}{x}$$

QUESTION 4:

The diagram (Fig. 4) shows the collector characteristics for a transistor in the common emitter mode. The transistor is normally biased with a 60µA base current. The supply is 9 volts and the load resistor is 1KΩ.

QUESTION 4 (a):

Draw the loadline and indicate the quiescent point Q. Show calculations.

ANSWER 4 (a):

Transistor Characteristics — COMMON EMITTER

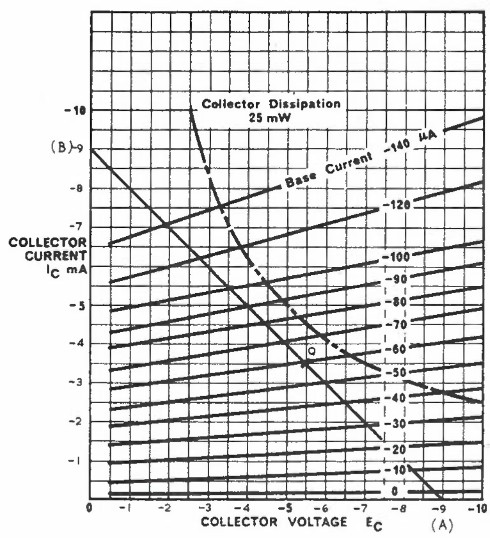


Fig. 4

First point (A), Ic = 0 and Ec = −9V

Second point (B), Ec = 0

$$Ic = \frac{Eb}{R_L} = \frac{9}{10^3} \times 10^3$$
$$= -9 \text{ mA.}$$

Loadline drawn on Fig. 4.

QUESTION 4 (b):

State the values of Ic and Ec when no signal is applied.

ANSWER 4 (b):

Reading off Fig. 4 corresponding to quiescent point Q;

Ic = -3.5mA

Ec = -5.5V

QUESTION 4 (c):

Calculate the power gain when a 30mV sine wave input signal of 30µA peak current is applied in series with the bias. Show all working.

ANSWER 4 (c):

Input signal = 30μA peak.

From Fig. 4.

Current gain (-5mA to -3.5mA)

$$= \frac{\Delta Ic}{\Delta Ib} = \frac{1500\mu A}{30\mu A}$$

$$= 50.$$

Voltage gain (-5.5V to -4.0V)

$$= \frac{\Delta V\ out}{\Delta V\ in} = \frac{1500mV}{30mV}$$

$$= 50.$$

Power gain = current gain × voltage gain

$$= 50 \times 50$$

$$= 2500$$

QUESTION 4 (d):

In the space provided, plot the dynamic Ib/Ic characteristic curve which corresponds to the 1kΩ loadline.

ANSWER 4 (d):

See Fig. 5.

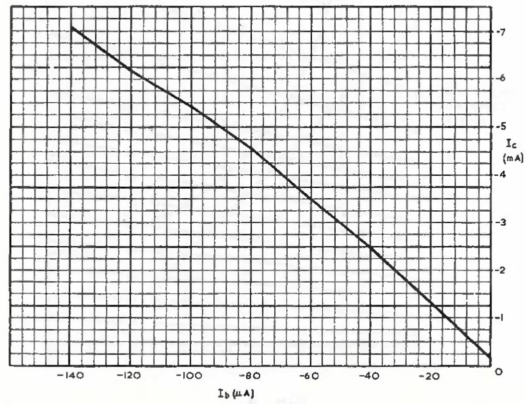


Fig. 5

QUESTION 5 (a):

(i) State the basic requirements of an oscillator and illustrate with a labelled block diagram.

(ii) Briefly explain the use and meaning of positive feedback in oscillators.

ANSWER 5 (a):

(i) See Fig. 6.

A network or tuned circuit to confine the oscillations to the required frequency.

An amplifier with sufficient power output to meet the load requirements and replace the energy lost in the circuit.

Positive feedback or regeneration to sustain the oscillations.

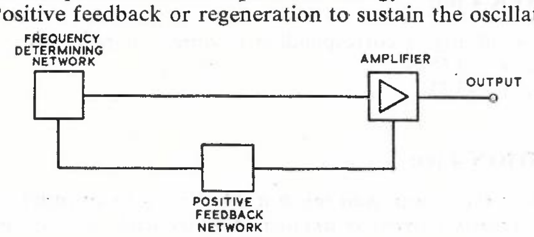


Fig. 6

(ii) Positive feedback is used in oscillators to feed a portion of the output voltage back to the input to sustain oscillation. Positive means that the signal feedback is in phase with the input. A phase change of 180° takes place in the common emitter transistor amplifier and the feedback network used must introduce a further shift of 180° so that the complete loop is 360° or in phase. Variable resistors are sometimes used to control the amount of feedback.

QUESTION 5 (b):

(i) Draw and label a block diagram which illustrates the basic principles of a Beat-Frequency Oscillator (B.F.O.).

(ii) State the main advantage of the use of a B.F.O. as a test oscillator over a variable frequency L/C oscillator.

ANSWER 5 (b):

(i) See Fig. 7.

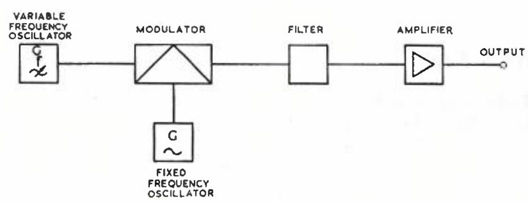


Fig. 7

(ii) A single oscillator using variable capacitors or inductors cannot be tuned over a wide band without switching in different components to give several consecutive ranges. This can be inconvenient in test oscillators. The B.F.O. overcomes this disadvantage.

QUESTION 6 (a):

Complete the diagram (Fig. 8) to show the differences between amplitude, frequency and phase modulated waves produced by the rectangular wave modulating signal.

ANSWER 6 (a):

See Fig. 8.

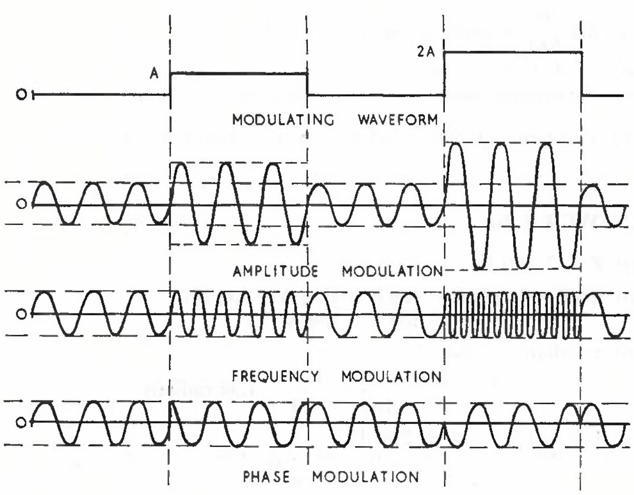


Fig. 8

QUESTION 6 (b):

Define phase modulation and briefly explain the similarities and differences between a frequency modulated and a phase modulated system.

ANSWER 6 (b):

Phase modulation is the process of combining the signal and the carrier frequency to produce a modulated wave which is shifting in phase in accordance with the signal amplitude and frequency. The number of degrees of phase shift is dependent upon the signal amplitude. The rate of phase shift from one value to another is dependent upon the signal frequency.

As phase modulation causes the frequency to be affected, a form of frequency modulation takes place. The waveshape produced is similar to the frequency modulated waveshape and can be detected and received by the same receiver as for the FM wave.

The only difference in the two systems is the manner in which the modulation is accomplished. Maximum and minimum frequency points with FM occur when the amplitude of the modulating signal is maximum in either direction. In PhM the frequency of the modulated wave is maximum when the rate of change of the modulating signal is greatest in one direction and minimum when in the opposite direction.

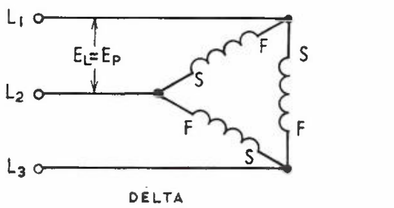
QUESTION 7 (a):

With the aid of sketches, describe the delta and star methods of connecting the windings of a three phase A.C. generator. In your answer give particular reference to phase voltages (E_p), line voltages (E_L), the neutral point, and the start (S) and finish (F) ends of the windings.

ANSWER 7 (a):

See Fig. 9.

Delta Connection. The windings are connected in series to form a closed circuit and the line wires L1, L2 and L3 are connected at the junction points. A neutral wire is not available in this connection.



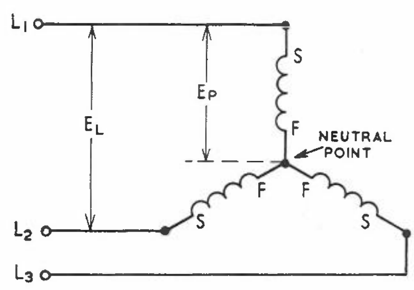


Fig. 9

As shown, the phase voltage E_p is equal to the line voltage E_L.

Star Connection. Corresponding ends (i.e. start (S) and finish (F)) of the three windings are connected together to form a neutral point. The line wires are connected to the other ends of the windings. The line voltage E_L is 1.732 times greater than the phase voltage E_p.

QUESTION 7 (b):

Complete the basic circuit of the three phase bridge rectifier, marking the polarity across the load. In the graph section provided clearly illustrate the waveform of the output current over one complete cycle.

ANSWER 7 (b):

See Fig. 10.

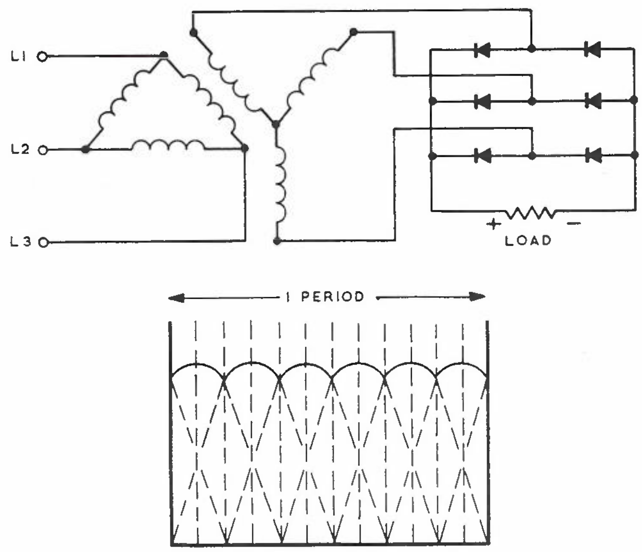


Fig. 10

QUESTION 8 (a):

Briefly describe the fundamental circuit features required of wideband or video transistor amplifiers.

ANSWER 8 (a):

Amplifiers with special compensating networks to increase the frequency response are referred to as wideband or video transistor amplifiers. The bandwidth of transistor amplifiers varies according to the type of transistor and the coupling arrangements used.

Transformer coupling is not suitable because of its many reactive elements and usually direct or R/C coupling is used. In each case the bandwidth can be extended by the use of negative feedback. Video signals and non-sinusoidal signals, such as used in oscilloscope sawtooth sweep circuits, have such a very wide range of frequencies which require the use of wideband amplifiers.

Compensating networks are used to increase the impedance in the collector circuit so that higher voltage and power gains will be obtained in the amplifiers.

QUESTION 8 (b):

With the aid of circuit drawings, describe the purpose and the operation of the following wideband transistor amplifier networks:

(i) High Frequency Compensation.

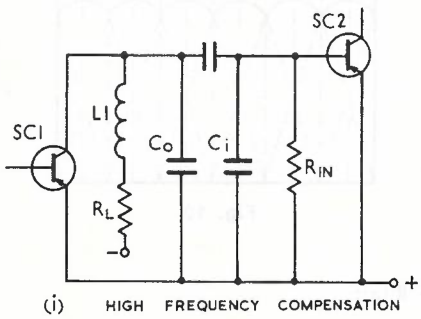
(ii) Low Frequency Compensation.

ANSWER 8 (b):

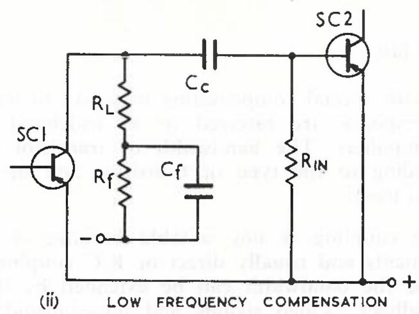
See Fig. 11.

(i) High Frequency Compensation (shunt peaking). The gain of an amplifier falls off at high frequencies due to shunt capacitance. To compensate, the collector impedance is increased by including an inductance L1 in the collector circuit. At high frequencies L1 has a high reactance and in conjunction with the shunt capacitances Co and Ci, forms a resonant circuit and increases the impedance of the collector circuit.
In series peaking, the inductance is added in series with Cc. Often both shunt and series peaking coils are included to obtain best results.

(ii) Low Frequency Compensation. The interstage coupling capacitor Cc has a high reactance at low frequencies, and most of the signal voltage is wasted across the capacitor instead of being applied to the next stage. To compensate for this loss, a network containing Cf and Rf is included as shown in Fig. 11. At high frequencies Cf has a low reactance and shunts Rf. At low frequencies the reactance of Cf is large; Rf is not shunted and this has the effect of increasing the impedance in the collector circuit and compensates for any loss across Cc.



(i) HIGH FREQUENCY COMPENSATION



(ii) LOW FREQUENCY COMPENSATION

Fig. 11

QUESTION 9 (a):

An inductor has an impedance of 400 ohms with an angle of lag of 60° when an alternating current (w = 1732 radians per second) is passing through it. Calculate its effective resistance and inductance at this frequency.

$$\left(\textit{Given } \cos 60° = \tfrac{1}{2};\ \sin 60° = \frac{\sqrt{3}}{2};\ \sqrt{3} = 1.732\right).$$

ANSWER 9 (a):

See Fig. 12.
Effective Resistance.

$$Z = 400\Omega \qquad \cos 60° = \frac{R}{Z} = \frac{1}{2}.$$

$$R = Z \cos 60°$$

$$= 400 \times \tfrac{1}{2} = 200\Omega$$

Inductance.

$$\sin 60° = \frac{X_L}{Z} = \frac{\sqrt{3}}{2}$$

$$X_L = Z \sin 60°$$

$$L = \frac{X_L}{w}$$

$$= \frac{Z \sin 60°}{w}$$

$$= 400 \times \frac{\sqrt{3}}{2} \times \frac{1}{1732} \times 10^3$$

$$= 200\text{mH}.$$

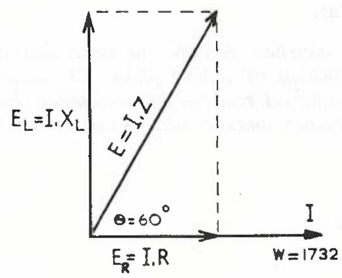


Fig. 12

QUESTION 9(b):

The diagram Fig. 13 shows the effect of frequency on the reactance o a series A.C. circuit, containing resistance (R), around its resonant frequency (fr).

(i) Draw three Vector diagrams to illustrate the circuit conditions (1) below, (2) at, and (3) above, resonant frequency.

(ii) Using operator j, state the circuit impedance of each of the three circuit conditions shown vectorially in (i).

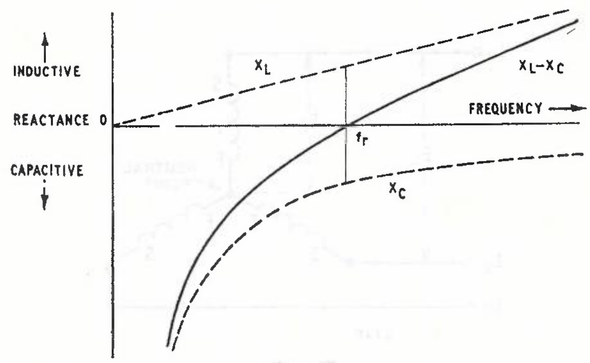


Fig. 13

ANSWER 9 (b):

(i) See Fig. 14.

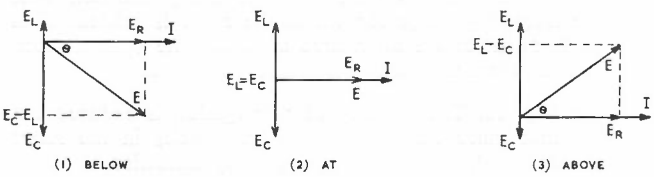


Fig. 14

(ii) below $Z = R - j(X_C - X_L)$
at $Z = R + j0$
above $Z = R + j(X_L - X_C)$

QUESTION 10 (a):

Define the following terms as applied to a waveform:

(i) Pulse.

(ii) Pulse Spacing.

(iii) Pulse Duty Factor.

(iv) Mark-to-Space Ratio.

ANSWER 10 (a):

(i) A Pulse is a sudden change of voltage or current of short duration, with the voltage or current having the same value both before and after the pulse.

(ii) Pulse Spacing is the time between corresponding points on two consecutive pulses.

(iii) The Pulse Duty Factor is the ratio of the pulse duration to the pulse spacing. It is also equal to the pulse duration times the pulse repetition frequency.

(iv) Mark-to-Space Ratio defines the ratio of pulse duration to the time from the conclusion of one pulse to the start of the next pulse.

QUESTION 10 (b):

The video waveforms on the anode of a video amplifier are shown in the diagram (Fig. 15) for a black picture signal and for a white picture signal. What D.C. anode voltage would be indicated by a moving coil meter for each signal condition?

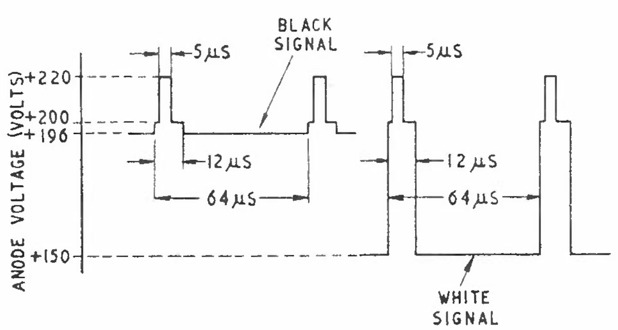


Fig. 15

ANSWER 10 (b):

Black Signal

D.C. Component = 196 volts + Average above 196 volts.

Positive area above 196V. $= \{(12 - 5) \times (200 - 196)\} + \{5 \times (220 - 196)\}$
$= (7 \times 4) + (5 \times 24)$
$= 148$ units

Negative area = 0 units

$$\text{Average voltage above } 196 = \frac{\text{Positive Area} - \text{Negative Area}}{\text{Total time}}$$

$$= \frac{148 - 0}{64}$$

$= 2.3$ volts

Therefore black signal D.C. component $= 196 + 2.3$
$= +\,198.3$ volts

White Signal

D.C. Component = 150 volts + Average above 150 volts

$$= 150 + \frac{\{(12 - 5) \times (200 - 150)\} + \{5 \times (220 - 150)\}}{64}$$

$$= 150 + \frac{700}{64}$$

$= 150 + 10.9$
$= +160.9$ volts.

QUESTION 11 (a):

Draw the basic circuits which illustrate the principles of the following:

(i) Three diodes used as an AND gate.

(ii) Two transistors used as a NOR (OR inverted) gate.

ANSWER 11 (a):

(i) See Fig. 16 (i). Each input must be at +9V before the output can be positive.

(ii) See Fig. 16 (ii). With either transistor 'on' a positive potential is obtained at the output.

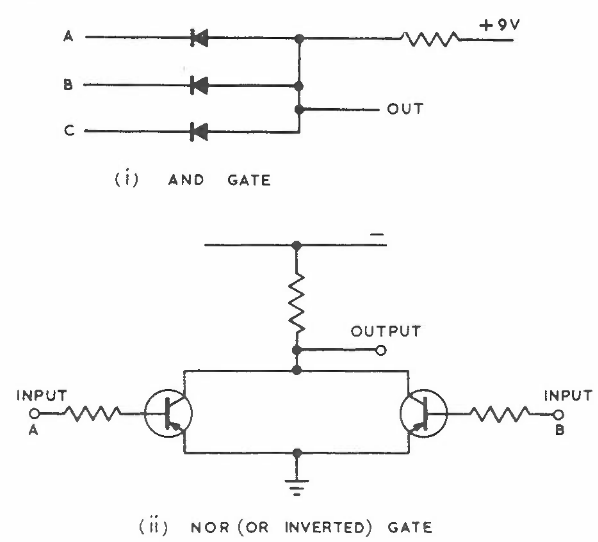


Fig. 16

QUESTION 11 (b):

In the circuit (Fig. 17) transistors are used to convert D.C. power to a different voltage. Briefly describe the operation of this circuit, indicating what additional equipment would be required to obtain a D.C. output voltage.

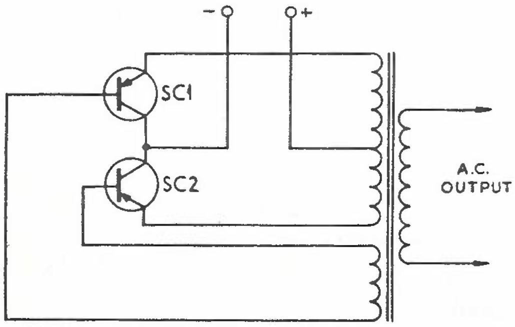


Fig. 17

ANSWER 11 (b):

The two transistors are used to switch on and off alternatively, inducing an alternating voltage into the secondary winding of the transformer in the following manner: When SC1 is building up to saturation, the e.m.f. induced in the feedback winding keeps SC2 at cut-off. At saturation of SC1, the induced e.m.f. ceases and SC2 begins to conduct. With current in SC2 increasing, an e.m.f. is induced into the feedback winding of opposite polarity and causes SC1 to be cut-off. This alternating action continues automatically. To obtain D.C. at the output a rectifier is used.

QUESTION 12 (a):

Briefly state the three main disadvantages of 'reflection', on a transmission line.

ANSWER 12 (a):

1. The power delivered to the terminal equipment is reduced.
2. The reflected waves distort the waveshape of the transmitted signal, thereby degrading the quality of the signal.
3. In some circumstances, the reflected wave may be heard as an echo in the transmitting equipment.

QUESTION 12 (b):

With the aid of graphical sketches, briefly explain how correct loading of cables controls the following features of cable transmission line signals:

(i) loss of signal level.

(ii) frequency distortion.

(iii) delay distortion.

(iv) 'reflection' of signals.

ANSWER 12 (b):

(i) See Fig. 18. The attenuation of the signal is reduced considerably over the frequency range for which the cable pair is loaded. Therefore overall signal level loss is reduced.

(ii) The attenuation constant becomes fairly constant over the frequency range for which the cable is loaded. Thus all frequencies are attenuated at nearly the same amount and therefore frequency distortion is reduced.

(iii) See Fig. 18. The velocity of propagation is reduced but becomes more constant for all frequencies in the range of the signal, therefore reducing delay distortion.

(iv) See Fig. 18. The characteristic impedance is increased but becomes more constant over the lower frequency range of the band being transmitted. This results in more accurate matching at take off points thus reducing 'reflection' of signals at the take off points.

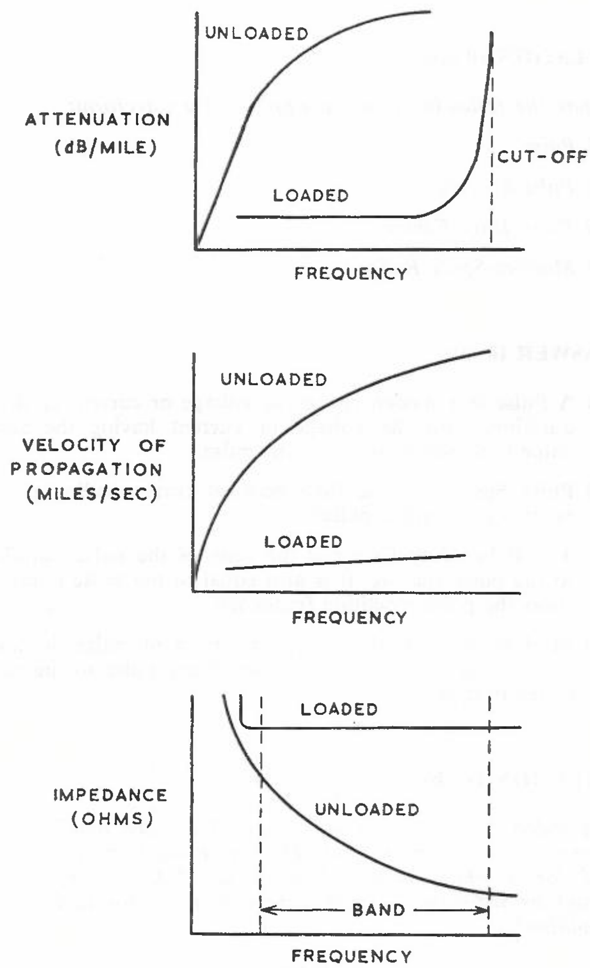


Fig. 18

QUESTION 13 (a):

Draw and label the circuit diagrams and vector diagrams of a 'perfect' transformer, which has a turns ratio of one, with each of the following load conditions:

(i) secondary winding open circuit.

(ii) Inductive Secondary Load.

(iii) Captive Secondary Load.

ANSWER 13 (a):

See Fig. 19.

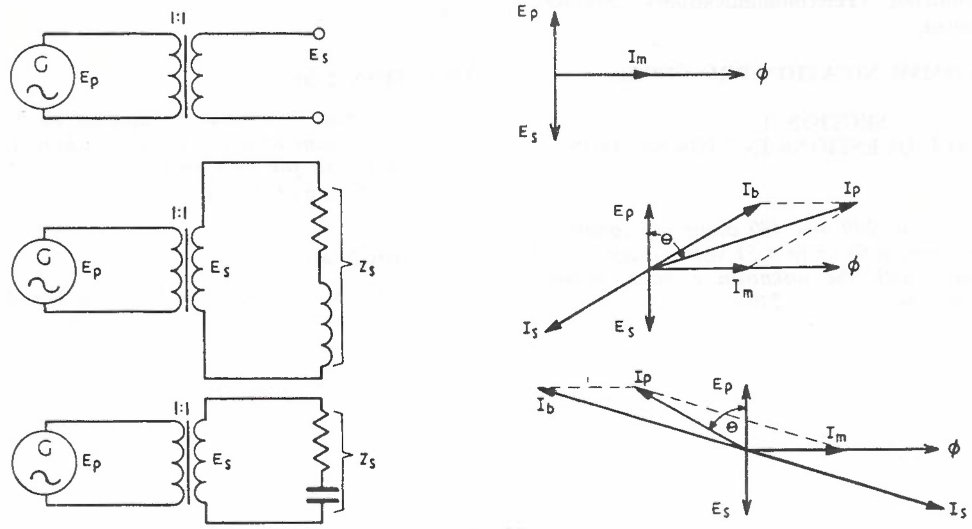


Fig. 19

QUESTION 13 (b):

State and briefly explain the three main losses which exist in practical transformers in addition to the 'Winding Loss'.

ANSWER 13 (b):

1. Eddy Current Loss. This is a power loss caused by the production of eddy currents in the core.
2. Hysteresis Loss. This refers to the energy spent in reversing the magnetisation of the core material.
3. Magnetic Leakage. This occurs when part of the flux from one winding does not link with the turns of the other winding. Its effect is to add to the inductive reactance of the windings and so reduce the secondary terminal voltage.

QUESTION 14 (a):

State the fundamental requirements, and illustrate with circuit diagrams, the two basic types of:—
(i) differentiating circuits, and
(ii) integrating circuits.

ANSWER 14 (a):

See Fig. 20.

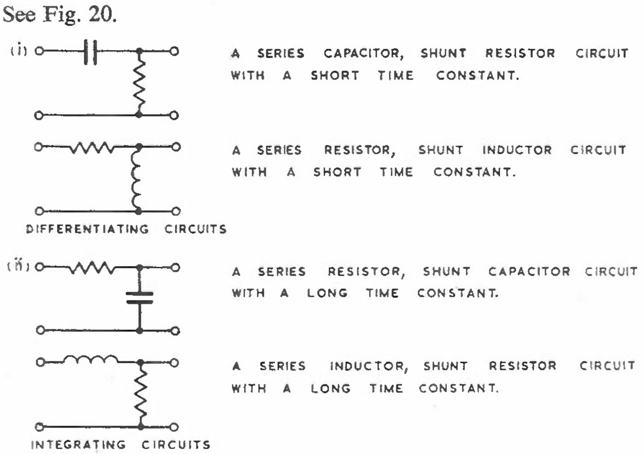


Fig. 20

QUESTION 14 (b):

Explain why a phase shift of approximately 90° is produced in a sine wave by a differentiating circuit. State what additional effect is produced when a sine wave of half the frequency of the original wave is differentiated with respect to the original unit of time and explain why this occurs.

ANSWER 14 (b):

Referring to Fig. 21, the maximum rate of change occurs at points A, C and E. The amplitude of the differentiated wave is therefore the maximum at these points as indicated by points A^1, C^1 and E^1. At points B and D the rate of change is zero and therefore the amplitude at points B^1 and D^1 is zero. The net effect is to produce a wave 90° out of phase and leading the original wave.

When the frequency is halved, the rate of change is halved at the maximum points. The differentiated wave therefore reaches its maximum amplitude in twice the time of the original wave. But as the time is actually the same, the wave reaches only half maximum amplitude. The effect is therefore to produce a wave of the same frequency, half the amplitude and 90° leading.

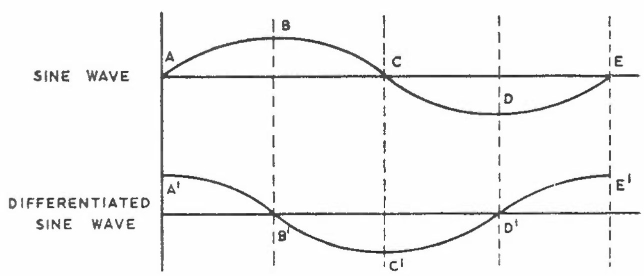


Fig. 21

Examination No. 5941-5945, 19th July, 1969, and subsequent dates to gain part of the qualifications for promotion or transfer as Technician (Telecommunications), Postmaster-General's Department.

TELECOMMUNICATION PRINCIPLES

SECTION 1
ANSWER ALL QUESTIONS IN THIS SECTION

QUESTION 1:

Two parallel resistors of 240 and 480 ohms are connected in series with an unknown resistor to a 51 volt battery. A switch is wired in parallel with the unknown resistor. When the switch is closed, the current in the 240 ohm resistor is 200mA. When the switch is opened, the power used by the 480 ohm resistor is 192mW.

QUESTION 1 (a):

Calculate the internal resistance of the battery.

ANSWER 1 (a):

With the switch closed, the circuit is as in Fig. 1.

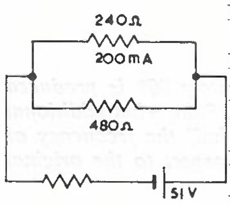


Fig. 1

$$
\begin{aligned}
I(480) &= \frac{200}{2} = 100\text{mA}.\\
I\ \text{total} &= 200 + 100 = 300\text{mA}.\\
E(240) &= I \times R = 240 \times 200 \times 10^{-3}\\
&= 48\text{V}.\\
E(\text{int}) &= 51 - 48 = 3\text{V}.\\
R(\text{int}) &= E/I = \frac{3}{300} \times 10^{3}\\
&= 10 \text{ ohms}.
\end{aligned}
$$

QUESTION 1 (b):

Calculate the value of the unknown resistance.

ANSWER 1 (b):

With the switch open, the circuit is as in Fig. 2.

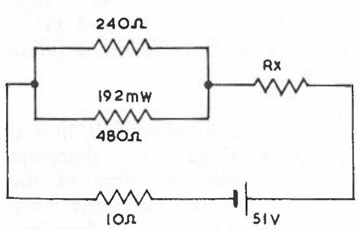


Fig. 2

$$
\begin{aligned}
I(480) &= \sqrt{P/R}\\
&= \sqrt{\frac{192 \times 10^{-3}}{480}}\\
&= \sqrt{4 \times 10^{-4}}\\
&= 20\text{mA}.\\
I(240) &= 2 \times 20\\
&= 40\text{mA}.\\
I\ \text{total} &= 40 + 20\\
&= 60\text{mA}.\\
E(\text{joint}) &= 40 \times 240 \times 10^{-3}\\
&= 9.6\text{V}.\\
E(\text{int}) &= 60 \times 10^{-3} \times 10\\
&= 0.6\text{V}.\\
E(Rx) &= 51 - (9.6 + 0.6)\\
&= 40.8\text{V}.\\
Rx &= \frac{40.8}{60 \times 10^{-3}}\\
&= 680 \text{ ohms}.
\end{aligned}
$$

QUESTION 1 (c):

Determine the p.d. across the unknown resistor when the switch is closed.

ANSWER 1 (c):

The switch is a short circuit when closed, therefore p.d. is zero.

QUESTION 2 (a):

A moving coil meter can be adapted to indicate alternating voltage by means of a full wave or a half wave circuit. Draw a typical circuit for each arrangement, and briefly explain the operation of one of the circuits.

ANSWER 2 (a):

A typical full-wave circuit is shown in Fig. 3 and a half-wave circuit in Fig. 4. The diode D2 in Fig. 4 may be omitted in some circumstances.

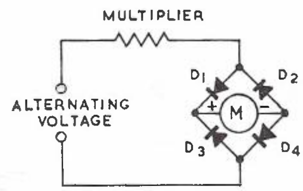


Fig. 3

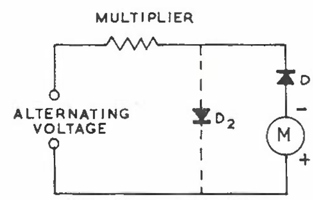


Fig. 4

When an alternating voltage is applied to Fig. 4, and the top terminal is negative, D1 conducts and D2 blocks. Current passes through the multiplier which drops the excess voltage, through D1 and the meter and back to supply. The next half cycle passes through D2 and the multiplier. The current through the meter is a series of d.c. pulses and it responds to the average value of these. Operation of Fig. 3 is similar, except that meter receives pulses for each half cycle, and responds to the average value of the two half cycles.

QUESTION 2 (b):

When an A.P.O. multimeter on the 30 volt D.C. range is connected to a constant voltage D.C. supply it indicates 10 volts. When switched to the 30 volt A.C. range it indicates 22.2 volts across the same supply. Explain why this reading is obtained, assuming that the meter and D.C. supply are operating correctly.

ANSWER 2 (b):

The A.P.O. multimeter is a half-wave meter and so responds to the average value of the half-wave pulses. However, the scale is calibrated in r.m.s. values and so on alternating ranges, the pointer indicates a value which is 2.22 times the average value of current through the movement. This indication is correct for sine wave signals, where the ratio of r.m.s. to half average is 0.707 to 0.318 or about 2.22 to 1. When d.c. is connected to a half wave rectifier meter, the movement responds to the average value (which in d.c. is the same as the r.m.s. value) and the meter indicates 2.22 times the correct value, or 22.2 volts instead of 10 volts.

QUESTION 3:

A circuit containing an inductance L, a resistance R and a capacitance C, all in series, is at resonance. Complete the table below to show the effects on the circuit conditions when the changes listed in the first column are made. Assume the supply has negligible internal impedance and use one of the following terms for each of your answers:

Increase *Increase to Infinity*
Remain the Same
Decrease *Decrease to Zero*

ANSWER 3:

CIRCUIT CHANGE	EFFECT ON				
	CURRENT IN R	VOLTAGE ACROSS R	VOLTAGE ACROSS L	VOLTAGE ACROSS C	CIRCUIT IMPEDANCE
Capacitance C Increased	Decrease	Decrease	Decrease	Decrease	Increase
Frequency Decreased	Decrease	Decrease	Decrease	—	Increase
Supply Voltage Increased	Increase	Increase	Increase	Increase	Remain the Same
Resistance R Open Circuited	Decrease to Zero	Remain the Same	Decrease to Zero	Decrease to Zero	Increase to Infinity

QUESTION 4 (a):

With the aid of a circuit, explain the effect on the operate and release times of a standard single coil relay when a rectifier (or diode) is connected across its coil.

ANSWER 4 (a):

When the circuit is completed, the rectifier is non-conducting, the current through the coil is not affected and the operate lag is normal.

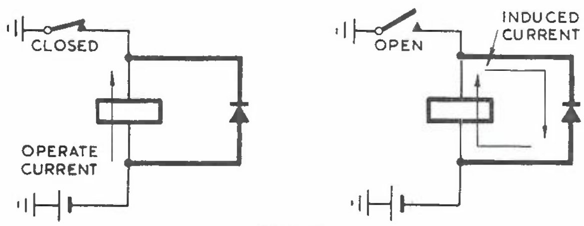


Fig. 5

When the circuit is opened, an induced e.m.f. is produced which is in such a direction to cause the rectifier to be conducting. Current passes through the coil and rectifier as shown. As the current through the coil is in the same direction as the normal current, the relay flux is maintained and the relay takes longer to release. As the flux decays gradually, the induced e.m.f. reduces and the current falls to the release value and the relay then releases.

QUESTION 4 (b):

The second winding of a double coil relay is wired to its own break contact as shown in Fig. 6. Briefly explain the effects of the contact and second winding on the operate and release times of the relay.

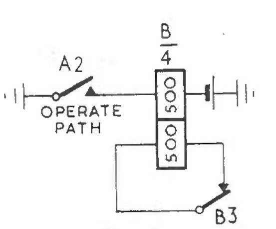


Fig. 6

ANSWER 4 (b):

The second winding is short circuited when the relay is not operated. When the operate path is completed, induced currents in the second winding produce a flux which opposes the flux in the operate winding (Lenz's Law). The resultant flux is less than the normal value and so the time for the relay to reach its operate value of flux is increased. When the relay operates, B3 opens the circuit of the second winding and it has no further effect.

The winding has no effect on the release time as the circuit of the second winding is not completed via B3 until the relay has released.

SECTION B
ANSWER THREE QUESTIONS ONLY FROM THIS GROUP

QUESTION 5 (a):

The capacitor in Fig. 7 is completely discharged. The switch is now moved from position 1 to position 2 for 5 time constants and then returned to position 1 for the same time. Draw labelled graphs of the approximate variation of E_R, and E_C, for these periods.

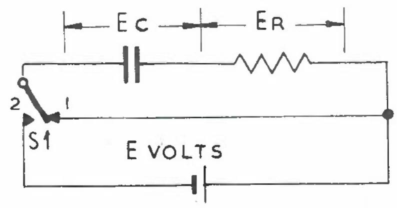


Fig. 7

ANSWER 5 (a):

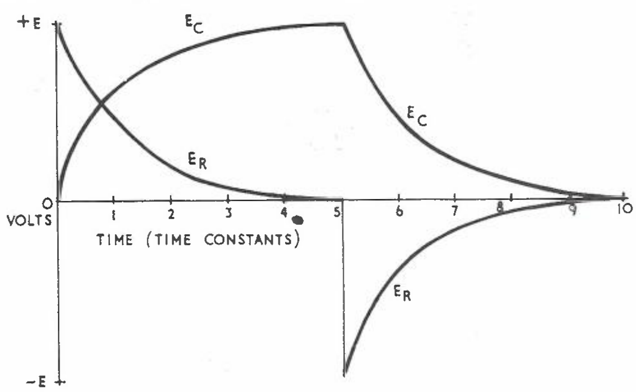


Fig. 8

QUESTION 5 (b):

The contact in Fig. 9 is moved from position 1 to position 2 for 50 milliseconds and then back to position 1. Assuming that the capacitor was fully discharged when the sequence commenced, calculate the p.d. across the capacitor 75 milliseconds after it returns to position 1.

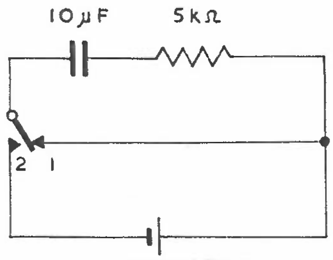


Fig. 9

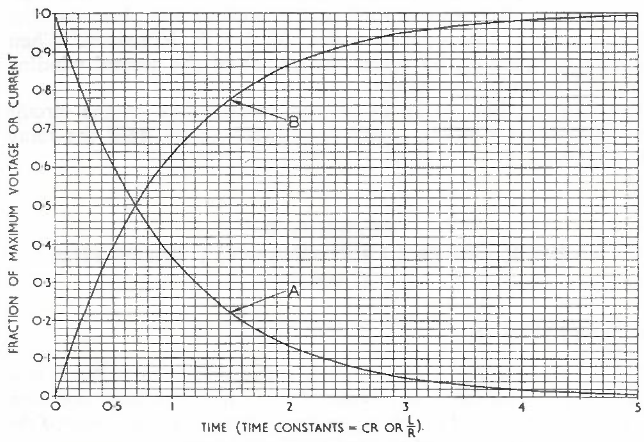


Fig. 10

ANSWER 5 (b):

Time Constant (mS) $= \text{C.R.} = 10 \times 10^{-6} \times 5 \times 10^{3} \times 10^{3}$

$= 50\text{mS}$

Charge time is therefore 1 Time Constant.

Ec at end of 1 T.C. is 63% of max. (from Fig. 10).

$$E_c = \frac{63}{100} \times 50 = 31.5\text{V}.$$

Discharge time is $\frac{75}{50} = 1.5$ Time Constants.

Ec at end of 1.5 T.C. discharge is 22% of max value (From Fig. 10)

$$E_c = \frac{22}{100} \times 31.5$$

$$= 6.93 \text{ Volts.}$$

QUESTION 6:

When a 600 ohm resistor, a 169mH inductor and a capacitor are connected in series to a 15 volt 1600Hz supply, the voltage across the resistor is 9 volts. Calculate the value of the capacitor and the phase angle, given that the circuit is capacitive (Use $2\pi = 6.25$).

ANSWER 6:

As the circuit (Fig. 11) is capacative, E_C must be greater than E_L (Fig. 12).

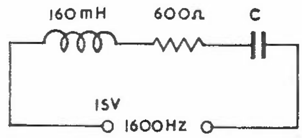


Fig. 11

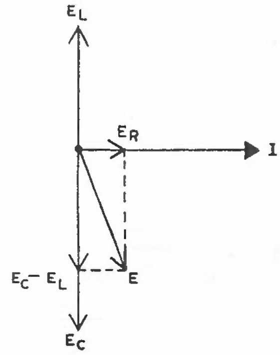


Fig. 12

$$X_L = 2\pi fL$$

$$= 6.25 \times 1600 \times 160 \times 10^{-3}$$

$$= 1600 \text{ ohms.}$$

$$I = \frac{E}{R} = \frac{9}{600} \times 10^{3}$$

$$= 15\text{mA}$$

$$E_L = I.X_L = 15 \times 10^{-3} \times 1600$$

$$= 24\text{V}$$

$$E^2 = E_R^2 + (E_C - E_L)^2$$

$$(E_C - E_L)^2 = E^2 - E_R^2$$

$$= 15^2 - 9^2$$

$$(E_C - E_L) = 12\text{V}$$

$$E_c = E_L + (E_C - E_L)$$

$$= 24 + 12$$

$$= 36\text{V}$$

$$X_c = \frac{E_C}{I} = \frac{36}{15} \times 10^{3}$$

$$= 2400 \text{ ohms}$$

$$X_C = \frac{1}{2\pi fC}$$

$$\therefore\ C(\mu F) = \frac{10^6}{2\pi f X_C}$$

$$= \frac{10^6}{6.25 \times 1600 \times 2400}$$

$$= \frac{1}{24}\mu F$$

$$\text{Tan } \theta = \frac{(E_L - E_C)}{E_R} = \frac{12}{9} = 1.33$$

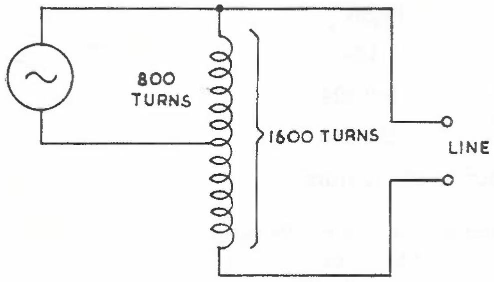
$$\theta = 53° \text{ leading}$$

QUESTION 7 (a):

An oscillator with an output impedance of 150 ohms is to be connected to a correctly terminated 600 ohm line via an auto-transformer which has a total of 1,600 turns, tapped every 100 turns. Show the connections required so that the oscillator and line are correctly matched (include working).

ANSWER 7 (a):

See Fig. 13.



$$\frac{Z_s}{Z_p} = \left(\frac{T_s}{T_p}\right)^2$$

$$\frac{600}{150} = \left(\frac{T_s}{T_p}\right)^2$$

$$4 = \left(\frac{T_s}{T_p}\right)^2$$

$$T_p = \frac{T_s}{2}$$

Fig. 13

Secondary is 1600 turns
therefore primary is 800 turns.

QUESTION 7 (b):

What would be the effect on the power delivered to the line if any other connection was used?

ANSWER 7 (b):

It would be reduced, as the oscillator would not be matched to the load.

QUESTION 7 (c):

A 600 ohm calibrated attenuator is connected between the transformer and line. If the oscillator output is 3 volts, calculate to the nearest dB the value to which the attenuator must be adjusted so that the power to the line is — 6dBm. (The transformer has no power loss.)

ANSWER 7 (c):

Fig. 14 shows the circuit.

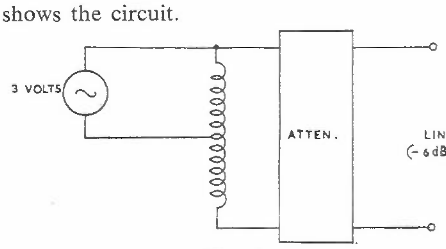


Fig. 14

$$\text{Osc. Power} = \frac{E^2}{R} = \frac{3 \times 3}{150} \times 10^3$$

$$= \frac{900}{15}\text{ mW} = 60\text{mW}$$

$$\text{dBm} = 10 \log \frac{P_1}{1}$$

$$= 10 \log 60$$

$$= 10 \times 1.78$$

$$= + 17.8\text{dBm.}$$

$$\text{Overall loss} = 17.8 - (-6)$$

$$= 24\text{dB}$$

QUESTION 8 (a):

The circuit current, in a parallel R, L and C network connected to a 16V supply, is 50mA. Given the circuit has a phase angle of 50° leading, calculate:
(i) the power factor;
(ii) the power dissipated;
(iii) the value of R.

ANSWER 8 (a):

The vector diagram is shown in Fig. 15.

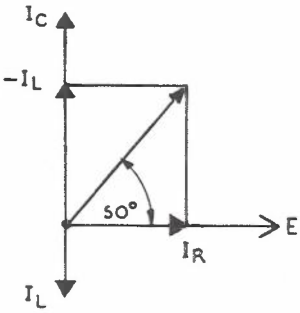


Fig. 15

$$\text{P.F.} = \cos\phi = \cos 50^\circ$$

$$= 0.64$$

$$\text{Power} = E \times I \times \cos\phi$$

$$= 16 \times 50 \times 10^{-3} \times 0.64 \times 10^3$$

$$= 512\text{mW}$$

$$\cos\phi = \frac{I_R}{I}$$

$$I_R = \cos\phi \times I$$

$$= 0.64 \times 50$$

$$= 32\text{mA}$$

$$R = \frac{E}{I_R}$$

$$= \frac{16 \times 10^3}{32}$$

$$= 500 \text{ ohms.}$$

QUESTION 8 (b):

State three ways by which the circuit above can be made to be resonant.

ANSWER 8 (b):

Decrease C
Decrease L
Decrease frequency

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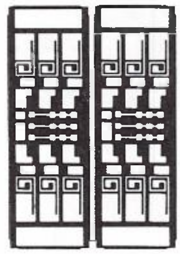
3	October	1969	195-268

(T.N.I. refers to a Technical News Item or a Letter to the Editors)

Answers to Examination Questions

IN MICROCIRCUITRY

how close can you photograph 2 objects and still have clear separation between their images?



WRAY GIVES YOU THE ANSWER:

This table shows the extremely high resolution of the Wray range of copying lenses. It assumes monochromatic light of 0.5461 μ and that the lenses are used at the conjugates for which they are designed. These resolution figures represent line pairs and do not count a black line and a white space as two.

**Also available is a 45mm. f/4 lens covering ½" square at a reduction ratio of 50:1 with a resolution of 280 lines/mm.*

Wray Precision Lens*	Reduction ratios available	9.5° semi-field (under-covering)	12° semi-field (normal)	14.5° semi-field (stretched)
3" f/4	25:1 10:1 5:1 2:1	¾" square 280 lines/mm.	1" square 240 lines/mm.	1¼" square 200 lines/mm.
5" f/4	40:1 20:1 10:1 5:1	1¼" square 240 lines/mm.	1⅔" square 200 lines/mm.	2" square 160 lines/mm.
10" f/4	20:1 5:1	2½" square 200 lines/mm.	3¼" square 150 lines/mm.	4" square 100 lines/mm.

Wray Microcircuit lenses are specially designed for a maximum area of coverage with the highest possible resolution. A wide range of Wray copying lenses is available through the Australian Distributors.

S&C 1925

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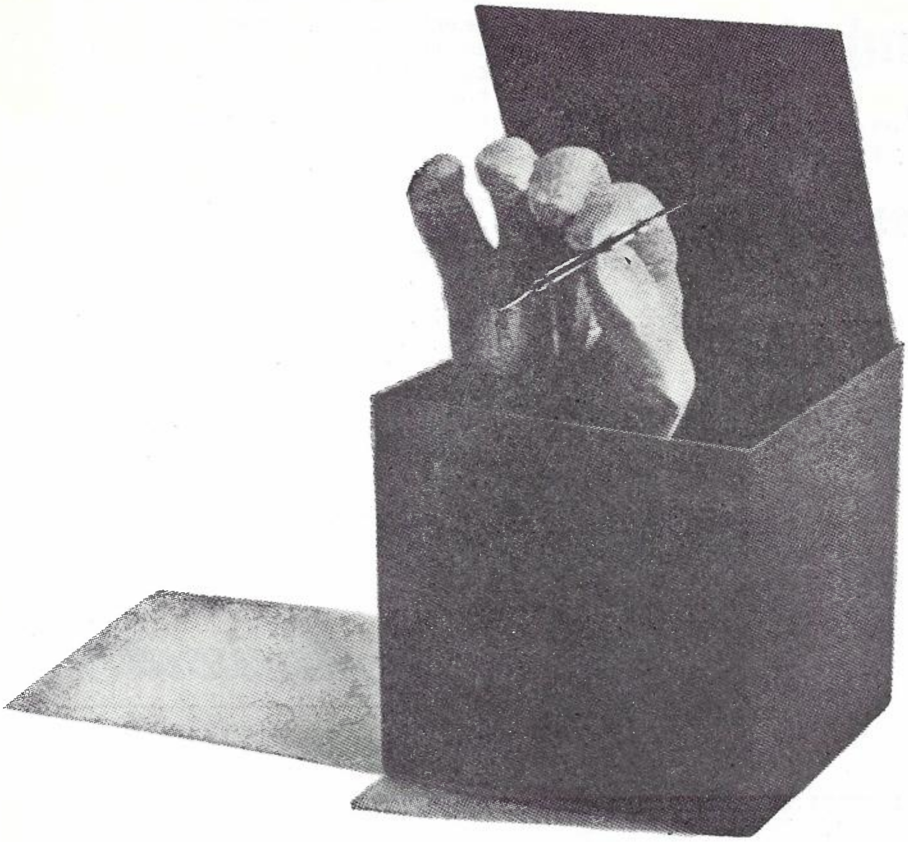
SC126

E G HOLT & ASSOCIATES PTY LTD

EVERY BLACK BOX SHOULD HAVE A DJINNI.



The reed switch is the greatest thing that's happened to electronic control devices since the Arabian Nights. It's encased in a little glass bottle you don't even have to rub. A coil turns it into a relay. A bar magnet makes it the most versatile electro-mechanical switch yet invented.

The reed switch is isolated in its glass container with a controlled atmosphere. It stays free of dust, damp and corrosion. There are no armatures, springs or pivots to wear. Life can easily exceed 100 million operations. Sensitivity is readily controlled. Speed is the next best thing to transistorized logic at a mere wisp of the circuit cost. Even RF switching is practical.

If this isn't magic, what is?

If you are not as familiar with magnetic reed switches as you should be, ask for technical literature. With this information at your finger-tips you may devise machine, flow or control uses no other engineer has conjured up yet.

IRH COMPONENTS PTY. LIMITED

A Subsidiary of International Resistance Holdings Limited

THE CRESCENT, KINGSGROVE, N.S.W. 2208, PHONE 50 0111

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HAMLIN INC

MAGNETIC REED SWITCHES.
THE FIRST AND FINEST IN THE FIELD.

2119

Facts

ON COAXIAL LINE EQUIPMENT

Facts and only facts count for Philips' family of coaxial line equipment. There are many striking facts worth mentioning.

Fact No. 1: Sound Design

Firstly, for the automatic compensation of the cable attenuation changes, the principle of pre/post-regulation is used. Half of the compensation is effected at the transmitting side (pre-regulation), the other half at the receiving side (post-regulation).
Secondly, only one of 36 repeaters is a surface station with one master regulator per direction. The remaining 35 are buried, three of them being remotely regulated and the remaining 32 non-regulated.
All level regulation is by remote control from surface stations thus simplifying the underground repeaters.

Fact No. 2: Proven Reliability — Experience.

The fact that many of these repeaters are submerged under the sea in Denmark and are used in Belgium, Sweden, Switzerland and the Netherlands indicates the confidence these administrations have in this series of equipments. Remember too that Philips was one of the first companies in the world to introduce underground repeaters.

Fact No. 3: Quality.

Quality is expressed in figures. Here are some for the 12 MHz system on normal coaxial cable (which is only one of the family).
Noise figure of the non-regulated dependent repeater: 3dB at 12 MHz.
Intermodulation noise: negligible (less than 10% contribution of total noise).
Total noise: 1 pW/km, under all operational conditions and for all channels. Accuracy of automatic compensation of seasonal cable-loss variations: within 1%.
Distance between power feeding points: 166km, all stations in between being underground. Line current: 50 mA DC. Maximum feeding voltage: 500 V between two inner conductors, with possibility of making a section voltage-free. Nominal repeater spacing: 4.7 km (max. acceptable repeater spacing: 5.2 km).

Fact No. 4: Installation.

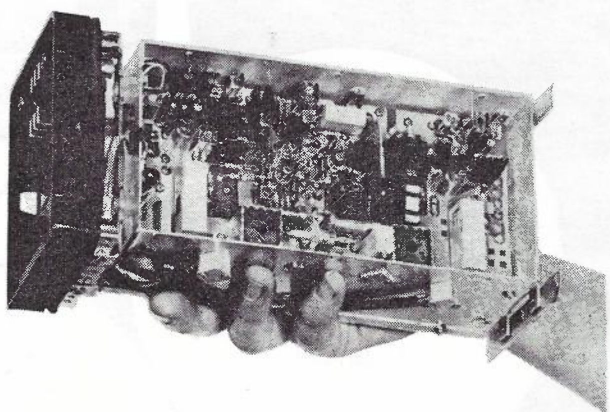
All dependent repeaters (regulated and non-regulated) are suitable for direct burial. The installation of these repeaters is not critical because they are highly insensitive to ambient temperature.
Special sea-cable cases are available.

Fact No. 5: Maintenance.

Maintenance is very simple and does not require any special skills. Philips actually taught a tea lady to operate the main line-up equaliser in a few minutes. This is possible because semi-automatic devices are employed to aid alignment and fault finding and such operations can be carried out during normal traffic.

Fact No. 6: Flexibility in Application.

Philips' coaxial line equipment is a family consisting of 4, 6 and 12 MHz versions for small-diameter (1.2/4.4 mm) and normal diameter (2.6/9.5 mm) cable. Bays, repeater cases, etc. are identical. Replacing a 4 MHz system by a 12 MHz system, for instance, merely means interposing new repeaters, while in the existing repeaters only plug-in conclave units need be replaced. All have the same safe line current of 50 mA. The repeater is so small that it can be mounted in a variety of underground housings including that designed by the Australian Post Office.



PHILIPS

Philips Telecommunications
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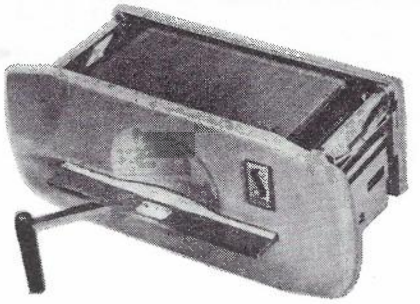
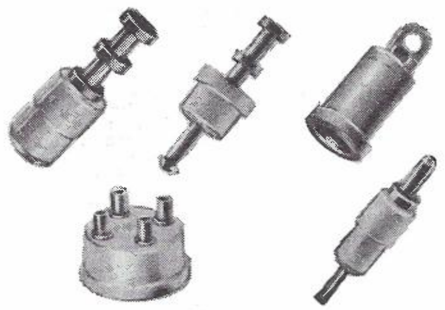
IRH Components Pty. Limited introduce Sealectro products for modern electronics.



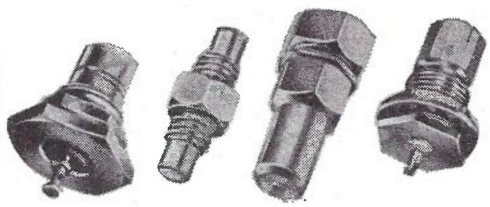
Sealectro card stub or badge readers

The Sealectro Static Punched Card or Stub Readers (80 x 12 or 51 x 12 cards) are suited to a wide and growing range of programming and matrix switching applications wherein immediate programme change and low volume programme store are requisite. Some samples are: Low-cost automation, machine tool control, automated testing, process control, function simulation. The Badge Reader (10 x 10 card) is designed for Personnel identification, Credit status, Data collection and transmission.



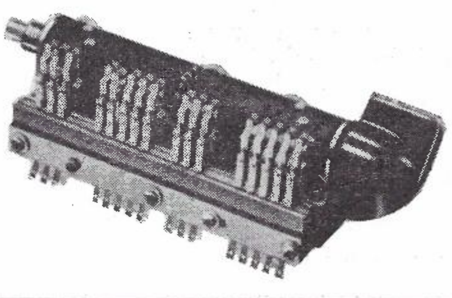
PRESS-FIT teflon terminals

The PRESS-FIT terminal range includes a broad line of types and sizes of Stand-offs, Feed-throughs, Receptacles, Test Point Jacks, Probes and Plugs, Transistor Sockets, Transistor Holders, Bushings, Taper-pin Receptacles and special types for welded or wire-wrap connections. PRESS-FIT terminals are available in the ten E.I.A. colours — white, black, brown, grey, blue, violet, green, yellow, red and orange.



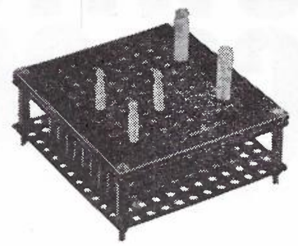
CONHEX® sub-miniature R.F. connectors

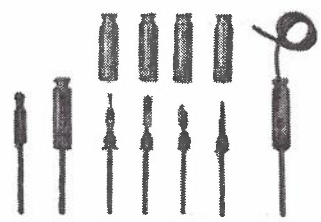
The widest range of Sub-miniature Coaxial Connectors, in screw-on, snap-on and slide-on styles. Conform to MIL-C-22557/A 50 ohm patterns available for RG—196/U or RG—188/U cables, and also for the equivalent semi-rigid cables. Hermetically sealed bulkhead mounting connectors suitable for pressurised equipment. A full range of BNC, TNC and C type adapters is also included in the ConheX range.



ACTAN programming switches

Drum type programming switches permanent or field adjustable. Manual or timing motor or stepping solenoid actuated. Extreme versatility of contact arrangements enable up to 60 discrete programmes per switch.





SEALECTOBOARD programme boards

The most flexible and reliable programming system, cord or cordless styles, single or multi-pole switching, programming by shorting pins or component interposition e.g. Diodes for back-feed elimination. Applications include: Analogue Computers, Naval Communications Channelling, Data Logging, Function Simulation, Pattern Generation, Factory Automation, Nuclear Power Control.

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 19 No. 3
OCTOBER 1969

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COVER
Blasting near
Coaxial Cables
(Picture shows effect
of exploding one
detonator in chalk.)

The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 19, No. 3

KIDD, G.P.: 'Mathematics of Reliability'; Telecom. Journal of Aust., Oct. 1969, page 223.

Definitions of the basic concepts (viz., the failure density failure rate and reliability functions, and mean life) necessary for the development of the theory are given in this paper. The properties of the Exponential, Weibull, Normal and Poisson distributions are summarised. Methods of calculating the reliability of series and parallel dependent systems and their variations are given, followed by a discussion on redundancy with and without repair of failed units.

LETTE, M. F.: 'Use of Explosives near Coaxial Cables'; Telecom. Journal of Aust., Oct. 1969, page 231.

This paper describes a field investigation on the use of explosives near a coaxial cable. Subject to stated safeguards the tests indicated that reasonably large-sized explosive charges may be detonated with safety near coaxial cables.

PARAPAK, J. L.: 'The Introduction of Electronic Devices into Electromechanical Telephone Equipment'; Telecom. Journal of Aust., Oct. 1969, page 215.

This paper discusses the problems which arise with the introduction of electronic devices into electromechanical telephone equipment. A general approach is presented which may be useful as a guide if such installations are considered. As an illustrative model, an electronic version of an outgoing relay set (FUR-T5F-H) developed by the author is described.

SANDER, J. E.; 'Numerical Design of Relay Circuits'; Telecom. Journal of Aust., Oct. 1969, page 197.

The use of a numerical method to design relay circuits can be advantageous whenever moderately complex, or very complex circuits are needed. The particular numerical method described in this paper is simple to apply with pencil and paper. It can also be programmed on a digital computer, and this makes it very easy to test a very large number of solutions to find the most economical circuit. An example of a computer designed circuit is discussed at the end of the paper.

SCOTT, F. M.. 'Key Logic Relay Circuit'; Telecom. Journal of Aust., Oct. 1969, page 203.

Non-locking push-button keys can be used to provide locking circuit functions by using relay sets to convert the non-locking action of the key. This article describes the functions provided by such relay sets.

SCOTT, F. M.: 'Some Interesting Circuit Elements'; Telecom. Journal of Aust., Oct. 1969, page 242.

This article describes some basic circuit elements used in the design of A.P.O. System AFM402. The elements include Switchboard Control Wire, Pick-up Timing, Line Relay Set Categories, Speech Path Switching, Backward Signal Reception and Repetition, Timer and Ring Control.

SCOTT, F. M.. 'System AFM402: Service Assessment Equipment'; Telecom.Journal of Aust., Oct. 1969, page 236.

This article describes the facilities provided on the A.P.O. System AFM 402 Manual Assistance Centres for assessment of grade of service provided by the centre.

TONG, Y. F.: 'Optimum Design of Tapered Busbar Systems"; Telecom. Journal of Aust., Oct. 1969, page 206.

This article presents an analytical method for the optimum design of tapered Busbar distribution systems. It develops a general theory from a basic model and gives an example of the application of the design procedure to an actual exchange Busbar System.

WARTH, J. W.: 'Transistorised Powerline Carrier Equipment'; Telecom. Journal of Aust., Oct. 1969, page 218.

This article describes single channel carrier equipment installed on N.S.W. Electricity Commission power lines.

WIELEBINSKI, R.: 'Antenna Measurements Using Natural Radio Sources'; Telecom. Journal of Aust., Oct. 1969, page 212.

High gain antennas of large aperture are needed for satellite communication systems and other space communication projects. This paper describes the use of radio stars for precise measurements of such antennae and an up-to-date catalogue of sources suitable for such work in the southern hemisphere is presented.

WILSON, A. B.: 'A Special Conference Circuit'; Telecom. Journal of Aust., Oct. 1969, page 248.

This article describes a special conference facility provided for Qantas to allow a conference call to be set up between an overseas line and a combination of exchange, P.A.B.X., and C.B. extension lines.