Presenting Maintenance Information

Techniques developed by B.B.C. use functional diagrams and minimum of text

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The introduction of the transistor and more particularly the integrated circuit have made possible the construction of extremely compact equipments. The extent of the miniaturization possible with modern solid-state devices is well illustrated by a typical integrated circuit which contains nearly one hundred transistors and as many resistors — all in a package measuring 1in by $\frac{1}{4}$in by $\frac{1}{8}$in! An equipment with fifty such i.cs would contain nearly 5,000 transistors: to use such a wealth of active devices would have been unthinkable in the days of valves. It is practical to employ active devices in such prodigal numbers and thus to construct equipments of very great complexity because solid-state devices are inherently reliable. Nevertheless modern equipments do develop faults which must be found and corrected and this article is concerned generally with the maintenance of modern solid-state equipment and in particular with the form in which maintenance information is presented in the B.B.C.

Factors influencing the form of maintenance literature

The following three features of modern equipment have a direct influence on the form of maintenance literature:

1. The complexity of modern equipment can be such that only the designer understands it thoroughly, and he is unlikely to be enthusiastic about calls on his time to maintain one of his earlier designs. It follows that the equipment must be maintained by staff who do not understand its method of working in detail: they must, of course, understand or be capable of learning its operation in principle, otherwise they would be incapable of locating a fault.
2. Integrated circuits and other packaged components such as thick- and thin-film circuits cannot be repaired if they fail: they are replaced if faulty. Thus maintenance staff do not need a detailed knowledge of the internal circuitry of such devices. They must, however, know sufficient about the function of the device, its input and output voltage levels, terminating resistances etc., to be able to test it. Again, therefore, the maintenance man needs a general rather than a detailed knowledge of the active device.
3. Because breakdowns are rare in modern equipment, maintenance staff have little experience of tracing faults in it. When a fault does occur the maintenance man has the problem of locating the fault in an unfamiliar equipment. Thus the maintenance information must be designed to assist the rapid location of faulty areas.

Such observations prompted the B.B.C. Technical Publications Section to devote some time to experiments on the form in which maintenance information for modern equipment should be presented.

It had been known for some years that maintenance men tended to rely on circuit diagrams and did not normally read associated text unless the diagram failed to give the required information. It was decided therefore to concentrate on diagrammatic forms of presentation and to reduce text to a minimum. In early experimental forms of literature care was taken to ensure that the diagram and associated text could always be seen at the same time and the normal arrangement was for text and diagram to be on facing pages. This was an improvement on earlier layouts but still required readers to switch their attention from one page to the other in following the operation of a complex circuit. Each time the reader returned to the text or to the diagram he had to find his place and this was felt to be an undesirable interruption to the continuity of the story.

Use of functional diagrams

There is no need to give details of the circuitry of packaged components such as i.cs but the function of such components must be indicated, otherwise it is impossible to follow the diagram.

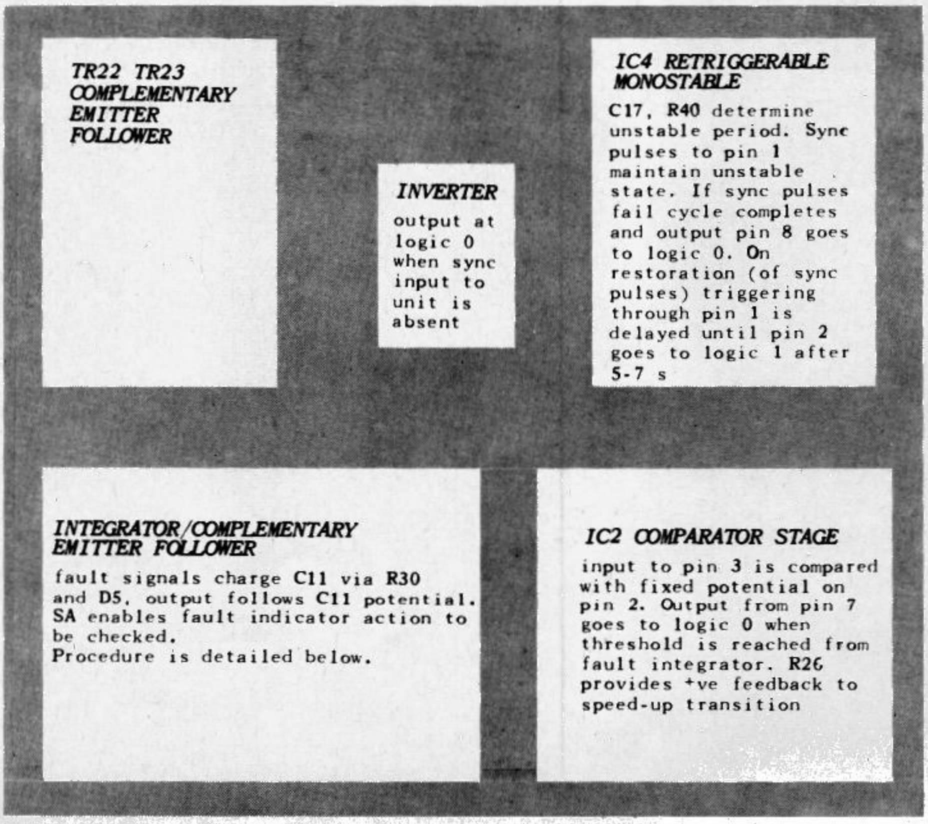

Fig. 1 Block text diagram facing circuit diagram, both divided into functional areas.

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The illustrations in this article are taken from original drawings intended for reproduction on A3 size paper (approximately 16½in by 11⅞in) in BBC Technical Instructions. To obtain illustrations of a size suitable for publication in *Wireless World* only part of each diagram is reproduced — sufficient to show the type of presentation described in the article. The backgrounds of the functional areas in Figs. 1 and 2 are printed in blue in BBC Technical Instructions but are shown as white boxes in the article. The circuit diagram of Fig. 4 is intended for reproduction in black and the explanatory notes in red but in this article the circuit is shown in white and the notes in black.

If the maintenance man is to be able to locate faults rapidly the diagram must show clearly the interrelationships between the stages which enable the equipment to achieve its purpose. Thus the diagram must show not only the function of i.cs but also those of other stages using for example discrete components. The functions of many basic circuits are obvious to experienced maintenance men because the circuits are (or should be) drawn with a standard layout which helps rapid recognition. Typical of such well-known circuits (which can be regarded as electronic building bricks) are common-emitter amplifiers, emitter followers, long-tailed pairs; a number of others are given in BS 3939. Although such circuits may be familiar they must be recognized before their function can be appreciated and this takes a finite time: recognition of an unfamiliar layout takes an even longer time. Thus it was decided that all stages should be labelled with their function.

Great care is taken in arranging the functional blocks on the diagram to obtain a clear signal flow and whenever possible this is from left to right and from top to bottom of the diagram: main signal paths can be printed in heavy lines to distinguish them from subsidiary signal paths.

To define the boundaries of the functional stages these are printed on blue backgrounds (shown as white boxes in Figs. 1 and 2) so that the blue areas with the associated signal paths form a block diagram in which each block represents a mathematical or logical operation upon a signal. A light blue was chosen for the background colour because it does not impede reading of the circuit if this is printed on it in black. An important point about this kind of diagram is that each block represents a circuit function and not an item of hardware. It could happen, for a particular equipment, that functional and hardware boundaries coincide but in general they do not. Functional diagrams aid fault location because they illustrate the division of the equipment into functions and thus give directly the information required to test any individual stage: to permit this the diagram must include terminal numbers, pin and socket connections etc., so that the input and output connections of each stage can be found on the equipment itself.

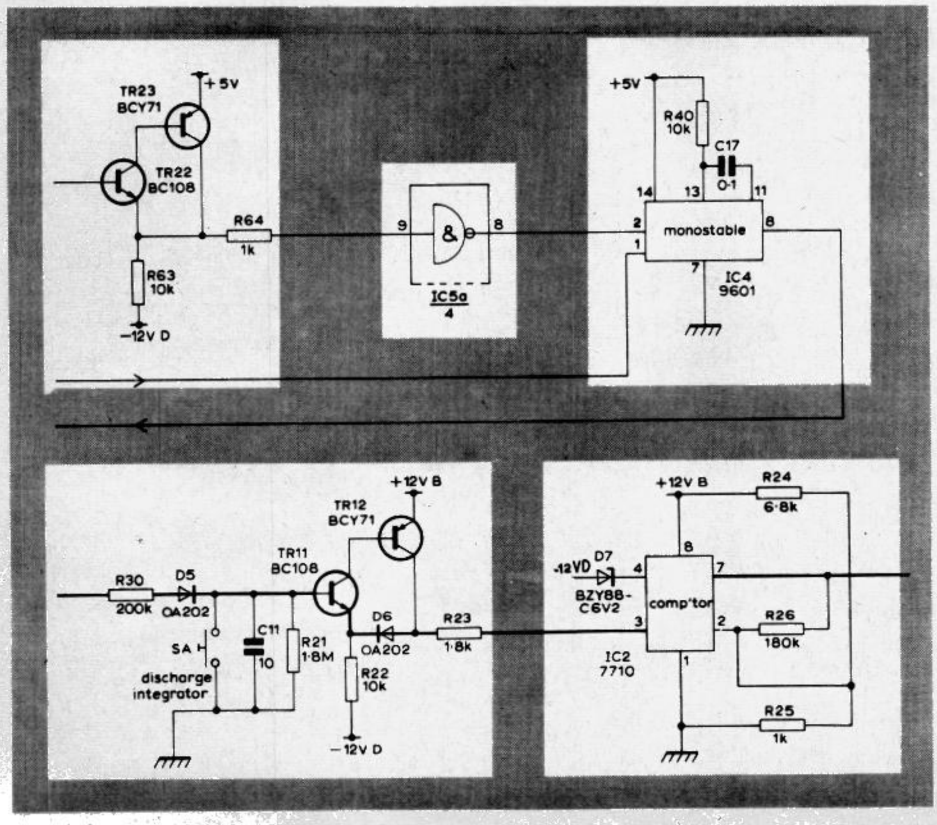
It can be assumed that a number of basic circuits such as common-emitter amplifiers and emitter followers are so familiar to the maintenance staff that no text is necessary to explain their behaviour. Other circuits require text and this was located, in earlier maintenance instructions, on the page facing the functional diagram. To minimize the difficulty of locating the text for a particular functional block the text was also printed on blue backgrounds of the same size as those of the functional diagram and arranged in the same layout. An example of such a pair of facing pages is given in Fig. 1. It is certainly easy to find a wanted text of a functional circuit stage but this form of presentation is still open to the objection that the maintenance man must consult two pages and must switch his attention from one to the other in following explanations of circuit behaviour. This form of presentation can also be criticized on the grounds of duplication: the breakdown of the equipment into functional areas is shown twice, one on each page. Both difficulties can be overcome by dispensing with the block text diagram and including the text within the blue areas of each functional circuit. An example of this form of presentation is given in Fig. 2: this gives the maintenance man on one side of a piece of paper most of the information he is likely to require on the particular part of the circuit featured.

Levels of treatment

For ease in handling, diagrams are limited in size to A3 and these are folded to A4 format for inclusion in standard folders which can be accommodated in normal-sized filing cabinets. The information which can be contained on an A3 page is limited, particularly when it is combined with text, waveforms, tables and other items of information. Thus a number of diagrams, possibly as many as 20, are required to describe a complete equipment such as one capable of generating all the standard waveforms required to line up a picture monitor.

To break-down the circuitry into 20 diagrams without destroying the continuity of the treatment requires some thought, and the technique adopted is to present the information at a number of levels. The first diagram in the service manual (level 1) is a diagram of the complete equipment divided into its major functions which are limited to about 20 which is the maximum which can be accommodated on an A3 page with ancillary text while maintaining adequate clarity of presentation. To limit the number of functions may require some of the functions in the level-1 diagram to be complex, and at this stage it may be sufficient to label a function for example as a waveform processor (without indicating how many stages it contains). Clearly a diagram as general as this cannot contain details such as i.cs, transistors, resistors, etc.

In subsequent (level-2) diagrams these complex functions are split into simpler



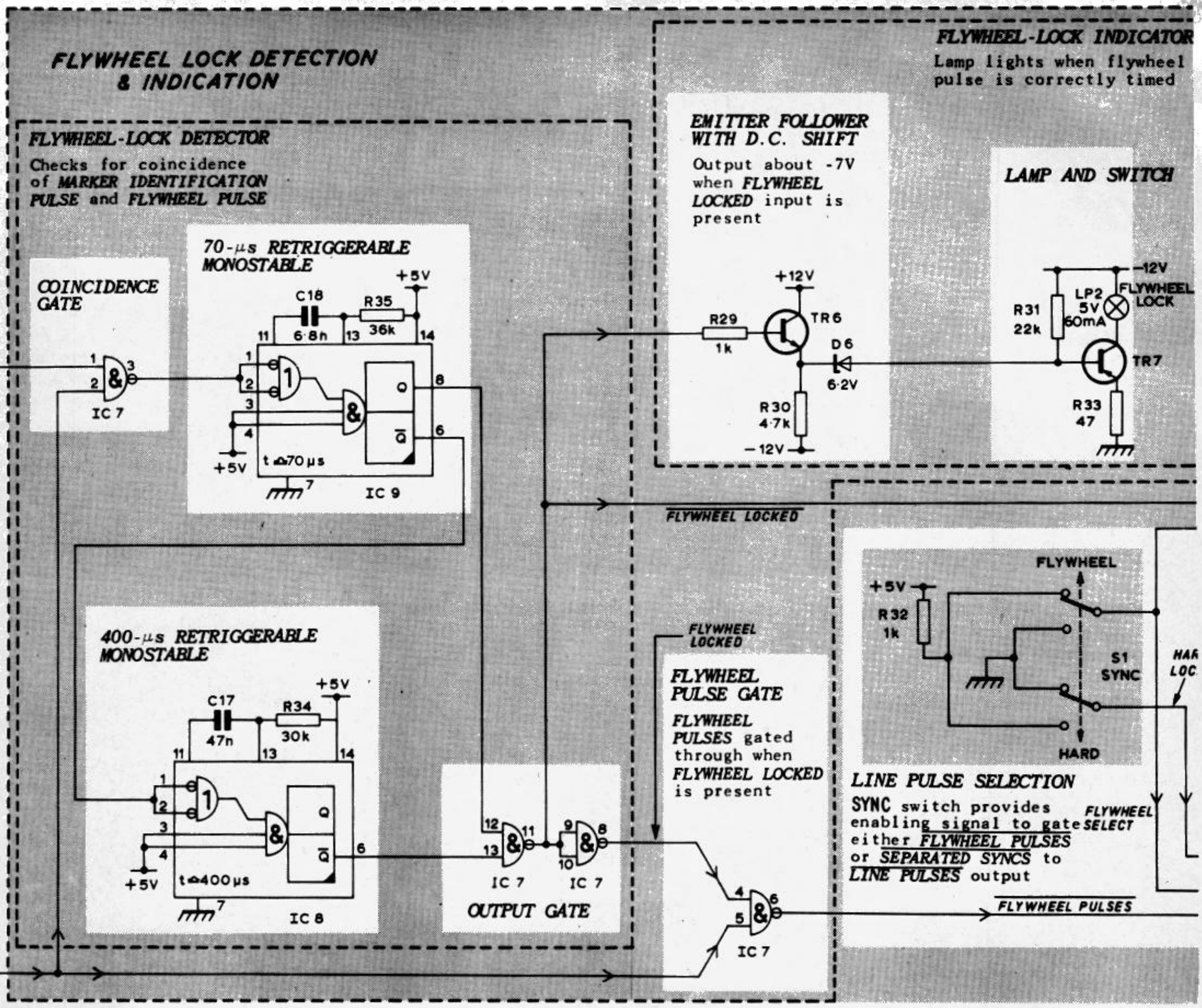


Fig. 2 Text combined with circuit diagram.

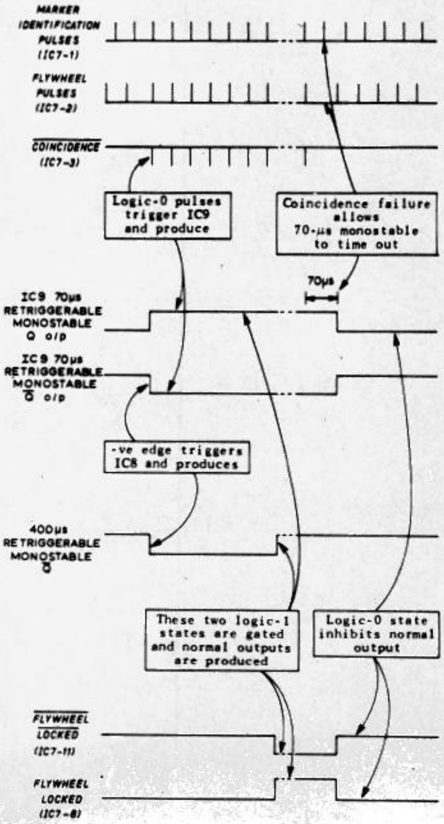


Fig. 3 A waveform-text diagram.

functions, these being again chosen to keep the total number of blue blocks per page to below 20. It may be that the functions in the level-2 diagram are so simple that the circuitry can be included within the blocks without overcrowding the diagram: if not then the functions can be subdivided further to a third level at which circuit details can be included.

In all diagrams it is essential, of course, that the functional blocks should be laid out so as to emphasize the paths of signal flow.

Waveform diagrams

For certain types of equipment the circuit behaviour is best explained with the aid of waveform diagrams. If the account is given in conventional text with reference to separate waveform diagrams the explanations can become tedious. The usual method is to allocate letters to the edges and other significant features of the waveforms and to use these letters in referring to these features in the text. Such a technique has the disadvantages already mentioned that the reader has to switch his attention between text and drawing. The repeated need of the reader to find his place in text and drawing is frustrating and wastes time: it can be avoided by using the technique employed in the functional circuit diagram, i.e. by condensing the text to a minimum, breaking it into sections and by inserting these sections at appropriate points in the waveform diagram (Fig. 3). There is then no need to label the waveform features because they can be identified by arrows. To distinguish it from the waveform the text is printed in a different colour.

Relay circuits

Few examples of technical writing can be so boring and repetitious as detailed descriptions of the operation of a circuit including a large number of relays. It is better to provide the information in the form of a table designed to illustrate the sequence of operations. If it is possible perhaps the best method of explaining the operation of the circuit is on the circuit diagram itself. This might be possible, for example, by stringing the individual circuits between horizontal supply lines and arranging them in the order in which they operate. By adopting this method what little explanatory text is still needed can often be accommodated on the circuit diagram itself near the circuit in question, thus avoiding any need for separate textual description. A sample of such diagram is given in Fig. 4.

Algorithms

One way in which it is possible to help inexperienced staff to maintain equipment is by the provision of algorithms: these are charts which enable faulty areas to be found quickly. The charts state, for example, what signals should be present at certain points in the equipment and, if they are missing or distorted, indicate what the next test should be and where it should be applied to obtain further information on the location of the fault. Thus the algorithms give information on the logical steps in fault-finding which a skilled maintenance man would take instinctively. A sample of an algorithmic chart is given in Fig. 5.

Algorithms can be useful but the staff using them still need some experience in tracing faults. For example, an algorithm may suggest that if a certain waveform is missing at a particular test point then the fault lies in a specified area of the equipment. But the waveform could be absent because of a poor soldered connection at the test point itself. It is impossible to include all such possibilities in an algorithm and they are therefore of limited application.

Physical location of components

The maintenance aids described above should enable the maintenance man to locate a faulty area in an equipment. However, additional information is needed to enable him to find any particular circuit point physically in the equipment and this is necessary of course during fault location. Functional diagrams can

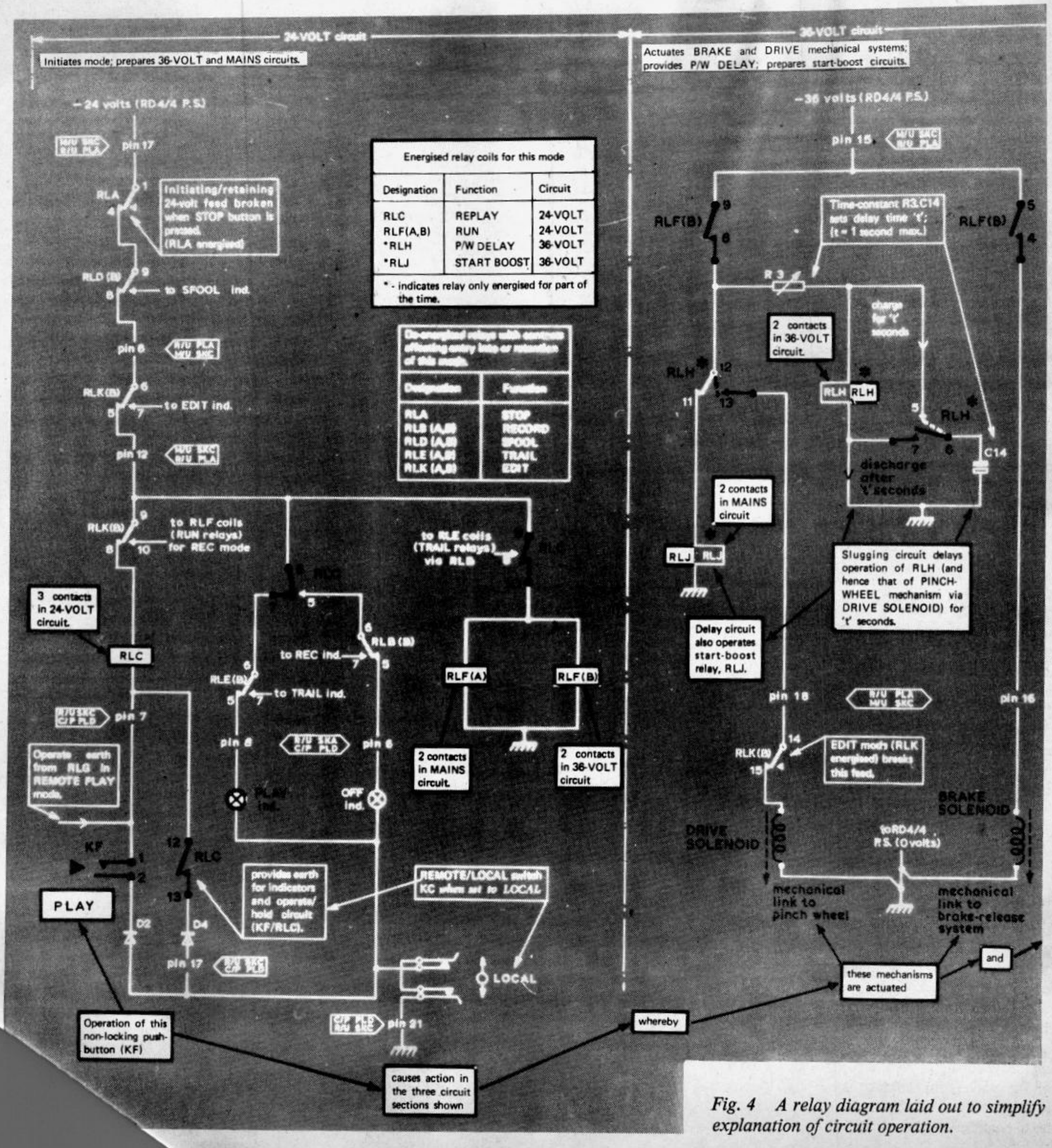


Fig. 4 A relay diagram laid out to simplify explanation of circuit operation.

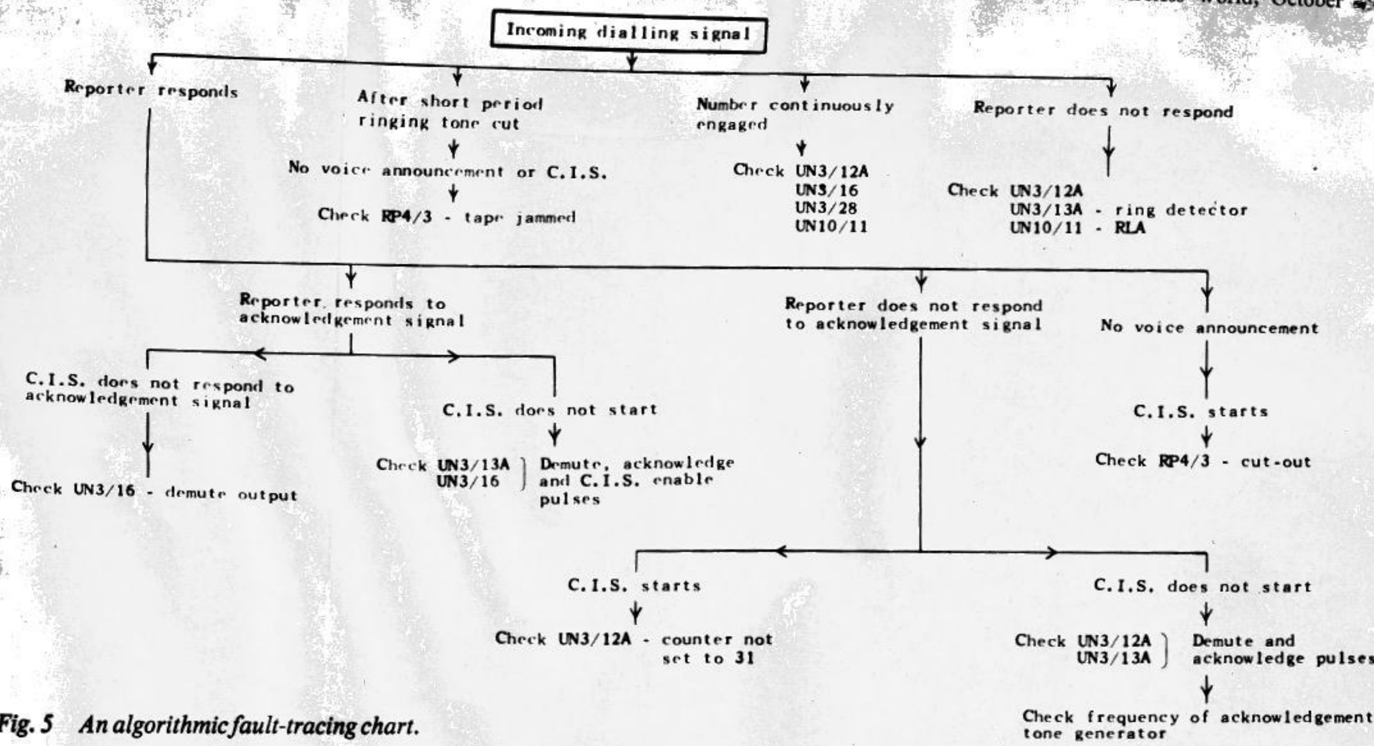


Fig. 5 An algorithmic fault-tracing chart.

provide some locational information if the terminals of transistors and the pin numbers of i.cs and of plugs and sockets are numbered. However, further information is required to enable, for example, the junction of a particular resistor and capacitor to be found physically. To this end diagrams showing the layouts of components on the printed cards are also provided and particular care is taken to identify test points on the cards.

Wiring diagrams

For equipment which consists of a number of inter-connected units it is essential, of course, to give complete information on the inter-unit wiring. This can be in the form of a diagram or a list of connections. Probably the diagram is better, particularly if it shows the units in their correct relative positions: this simplifies transfer of attention from the printed page to the equipment itself.

Parts lists

If a component is faulty it may still be recognizable and the type number may still be legible: all the information is then available to enable a replacement component to be obtained. Often, however, the faulty component has been destroyed (e.g. a resistor has burned out) or any markings on it have become illegible. The component cannot now be replaced until sufficient information on it has been obtained. The circuit diagram can supply some details, e.g. the resistance of resistors and the capacitance of capacitors, but this is often insufficient to enable a suitable replacement component to be obtained. Complete information on all components should therefore be included in the maintenance information. Equivalent components are sometimes satisfactory as replacements but there are some components for which replacements must be precisely the same type as those used originally.

Conclusion

The methods outlined in this article have been introduced into B.B.C. Technical Instructions over the last three years and are regarded by the maintenance staff as a considerable improvement over earlier methods of presenting maintenance information. In particular the reduction in the volume of conventional text and the introduction of the functional diagrams have been welcomed. Experiments in presentation will continue but it is anticipated that changes will be confined to details in the immediate future.

Books Received

Electronic Maintenance Management contains the contributions made to the 1973 Symposium of the Society of Electronic and Radio Technicians held at the University of Nottingham earlier this year. Subjects covered range through maintenance philosophies, technical documentation and design requirements to personnel organizations and careers. Speakers at the symposium represented all sectors of the industry from large to small specialized companies. Titles of the 21 papers contained in the proceedings include — Education and Training for Maintenance Management, The Economics of Servicing, Training in Fault Diagnostic Techniques, The Effect of Service on Design, The Use of Algorithmic Fault Finding Guides, The Maintenance Task on Commercial Computers — A Different Approach, and The Need for a Standard Format of Maintenance Data for Electronic Equipment. Price £5 (incl. p & p.). Pp. 189 plus unpaginated papers (3). Society of Electronic and Radio Technicians, Faraday House, 8-10 Charing Cross Road, London WC2H 0HP.

Search the Solar System by James Strong discusses the future role of unmanned interplanetary probes. Emphasis has now been placed on the continued exploration of the Solar System by probes similar to the "Mariner" reconnaissance of Mars and Venus and the "Pioneer" probe now on its way to Jupiter. Because every planet presents a fresh set of problems, various types of space probe will be necessary. Some will be purely reconnaissance orbiters while others will soft-land sophisticated capsules that will search for evidence of life on the surface by remote control. The author discusses ways of exploring hot planets, like Venus and Mercury, and how fast- or slow-moving comets can be intercepted. He also describes how to control a television-guided mobile probe, special balloon probes and radar satellites, how to explore the rings of Saturn, and describes a new way of maintaining continuous radio communication between Earth and a planetary surface anywhere in the Solar System. The book also describes the latest techniques for sending fast probes to the Outer Planets and a "kamikaze" probe to take close-up pictures of the Sun. Price £3.25. Pp. 160. David & Charles (Holdings) Ltd, South Devon House, Newton Abbot, Devon.

Included in recent additions to the list of books in the Foulsham-Tab series and published by W. Foulsham & Co. Ltd, Yeovil Road, Slough, SL1 4JH are:

Radio Control Manual — S[...]stems Circuits and Construction by Edward [...] Price £1.25. Pp.190.

Audio Systems Handbo[...] Crowhurst. Price £1.25. Pp[...]

New IC FET Princ[...] K.W. Sessions and D[...] Pp.160.

Simple Transistor[...] **and Students** by La[...] Pp.192.

Video Tape Pr[...] **Techniques** by J[...] Pp.252.