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TECHNICAL TRAINING COMMAND

TECHNICAL TRAINING COMMAND
ROYAL AIR FORCE
LABORE · TERRESTRI · CAELESTIS · VICTORIA

RESEARCH SECTION

ELECTRONIC DATA FLOW DIAGRAMS.

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Summary

The Research Section of Headquarters Technical Training Command has produced data flow diagrams for use in experimental fault finding courses. This booklet outlines the reasons for their use (paras.1 - 3), the principles used in drawing them (paras. 4 - 31), and the way in which they are used (paras.34 - 52). A list of general rules for drawing data flow diagrams is suggested (paras. 32 - 33).

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ELECTRONIC DATA FLOW DIAGRAMS

INTRODUCTION

1. One of the major tasks of Technical Training Command is to teach men how to maintain electronic equipment. In addition to the knowledge and skills acquired through training, the fitter has the use of several types of job performance aid. The circuit and block diagrams in technical Air Publications are one form of job aid. If these diagrams are drawn in such a manner that the fitter can readily find the information and guidance which he requires, the efficiency of maintenance work is improved and the training task is made easier.

2. One approach to the drawing of these diagrams is to illustrate the function of the equipment by emphasizing the path of the signal flow through the components. This method has been called the "data flow" approach. It has been used in experimental fault finding courses on radar equipments. Together with the use of a logical fault finding technique, the method appears to go some way towards easing the maintenance task.

Aim of the Booklet

3. The following notes indicate the way in which data flow diagrams have been drawn and used by Technical Training Command Research Section. It is felt that these notes will be of assistance to training staff who are concerned with the preparation of diagrams for electronic equipments. Although general rules for drawing data flow diagrams have been given, no attempt has been made to lay down detailed drawing specifications. While the booklet is written from the point of view of providing diagrams for use in fault finding, it is thought that data flow diagrams would be of use in most forms of electronic maintenance.

PRINCIPLES OF DATA FLOW

4. In data flow diagrams (and data flow instruction e emphasis is on the flow of information, i.e. the paths of sig through the equipment irrespective of the physical units through they pass. The purpose of data flow diagrams is to show the rout of signal paths through an equipment, from inputs to outputs in simplest manner possible, thus laying bare the functions of th uipment and the inter-relationships between the component parts.

5. The problem of the inter-relationship of the parts is an important one in fault finding as it is necessary to know which parts of an equipment could cause a particular fault symptom. With conventional diagrams it is often difficult to sort out these inter-relationships. Data flow diagrams present exactly the same information as should be contained in conventional diagrams, the difference being merely in the presentation of the information.

6. To draw data flow diagrams, an equipment must be divided into parts which perform specific functions such as transmission, time base generation, or mixing, and not divided according to its physical layout. In some equipment the functional layout will correspond with the physical layout and an equipment designed with maintainability in mind should certainly fit in with this requirement. Unfortunately in most equipments, certainly airborne equipments, the requirements of serviceability and maintenance are outweighed by those of performance, speed and cost of development, and space.

7. Functional rather than physical layout is therefore the principal difference between data flow diagrams and conventional diagrams, and this difference is clearly illustrated in the examples discussed in the following paragraphs. Figure 1, "Extract from an Orange Putter Chain Diagram (1)" is a simple example. It shows part of a lead carrying the variable gain control voltage between two points in Orange Putter. The lead is shown as a straight line irrespective of the fact that it passes through 5 plugs located on three different physical units. To follow this lead in the equipment A.P. would require the use of four separate diagrams. The white number in a black circle indicates an accessible test point. How this portion of data flow path fits into a complete chain diagram can be seen by comparing it with Figure 3, Orange Putter Chain II.

8. Physical layout information is, of course, still required for the purpose of component location and if this information is not provided on the data flow diagrams it should be provided as support information.

9. If information about an equipment is illustrated in the data flow manner, it follows that the equipment should also be taught in this manner, commencing with the overall function of the equipment and proceeding to the functional chains and circuits. Conventional equipment instruction usually starts with the block diagram, but drifts into a physical box-by-box explanation rather than a functional one.

TYPES OF DATA FLOW DIAGRAM

10. Data flow diagrams can be divided into three types: circuit diagrams, chain diagrams, and block diagrams. The object of each is discussed below.

Circuit Diagrams

11. Circuit diagrams should illustrate circuit detail down to component level. In general they should shown all of the components required to perform a simple function in the equipment, e.g. pulse

generation, amplification, oscillation, or counting. This should not restrict them to one valve or semiconductor stage, although, in many cases, only one valve or semiconductor device is used. Examples of multistage circuit diagrams would be multistage amplifiers, amplifier and cathode follower, paraphasee amplifiers, cascode stages, and stabiliser circuits.

12. Every circuit diagram should be drawn according to the data flow principles outlined in paras. 4 - 9. To apply these principles all inputs and outputs should be in specific positions on the diagram, e.g. outputs on the right hand side and inputs on the left hand side of the diagram, with the main signal path in a straight line through the centre. If there is more than one stage, the stages should be shown in positions suited to their function.

13. The layout of circuits should be standardised as far as possible and all the information required to fault find within a circuit should be given with or on the diagram, e.g. resistance values, valve pin numbers, waveforms, layout diagrams. The object is to reduce the amount of searching necessary to obtain relevant data.

14. Figure 2, Orange Putter Co-incidence Circuit, shows an example of a circuit diagram drawn both in the conventional and data flow manners. Figure 2a shows the co-incidence circuit as illustrated in the fault diagnosis section of the A.P. It is part of a larger diagram showing all the circuitry on chassis 3, not all of which is related to the same function. Figure 2b illustrates the same circuit drawn in the data flow manner. A comparison of these two diagrams shows how the principles of data flow have been applied to the co-incidence circuit. Figures 2c, 2d and 2e illustrate the additional information supplied with the data flow diagram for fault finding purposes.

15. Consider Figure 2b. The main difference between the original and the redrawn diagrams is that the inputs and outputs to the circuit are clearly shown and that the components are grouped on a functional basis. The circuit number and title appear at the top of the diagram and so does a Roman numeral indicating the chain in which the circuit appears. Since a separate layout diagram has not been drawn for this circuit, direction is given to the main layout diagram in which it is shown (CHASSIS 3). At the bottom of the diagram a space is provided in which attention can be drawn to the controls in the circuit (potentiometers, switches etc.), although, in this case, the circuit contains no controls. Also, at the bottom of the diagram, reference is made to the circuit in which the heater supplies are illustrated. The test point (17) is an external one used in conjunction with an Orange Putter test equipment and its full details appear with the appropriate chain diagram (Chain II see Figure 3). The convention of having H.T. and earth rails has been abandoned in the data flow diagram to avoid confusion between supply and signal inputs and to prevent stages which are not functionally related being joined by a lead.

16. Figures 2(c) amd 2(d) illustrate the waveforms which should be obtained at numerous points in the circuit when the circuit is functioning correctly. The control settings used to obtain these waveforms and the conditions under which they were obtained are also noted. Two waveforms are given for the anode of V 804B since the circuit is d.c. coupled to the following circuit and it is necessary to remove a succeeding valve (V805) to isolate it conclusively (see paragraph 20).

17. Figure 2(e) shows tables of resistance and voltage measurements throughout the circuit. As this material was provided for students who had a minimum of theoretical knowledge, care has been taken to resolve the problem of parallel paths when making resistance measurements, and a note is made of those components which must be disconnected before a true measurement of their value can be obtained.

18. A close look at figures 2(c), 2(d) and 2(e) will reveal that some of the information is redundant in that it is duplicated or can be read from the circuit diagram (there is no need for resistance measurements from valve pin 7 for instance). This has arisen because of the way in which the material has been produced and used in Research Section tasks.

19. In brief, the data flow diagram shows clearly the function of the circuit. It is easy to trace the path of the signal through the circuit and to work out the theory of the circuit's operation, if this is required. For example, it can be seen from the data flow diagram that the three inputs are combined in an anode load common to the three triodes, and that the combined signal is amplified in the simple triode amplifier V804B.

Conclusive Isolation of a Circuit

20. To assist fault finding procedures it is necessary to ensure that a particular faulty circuit can be conclusively isolated. That is, if a circuit has a correct input and an incorrect output, the fault finder requires to know whether the fault is conclusively in that circuit, or whether the output of the circuit could have been measured as incorrect due to a fault in a succeeding stage. For example, if a two stage RC coupled valve amplifier was split into two circuits A and B, and the division between circuits was made on the B side of the coupling capacitor, then a grid/cathode short circuit in stage B would make the output of A appear incorrect. In the absence of better information the fault finder might make the wrong deduction i.e. that the faulty component must be in circuit A, the input of which is correct and the output of which is incorrect. An important factor in splitting up the circuits is therefore to determine exactly where a split should occur, bearing in mind that faults may have an effect on stages preceding the actual faulty stage.

21. With valve circuits the problem is simplified in that early stages are relatively insensitive to fault conditions in later stages. An open circuit anode load, for example, will have little or no effect on the output of its preceding stage. However, even in valve circuits, there are still a few components which it is difficult to allocate to a particular circuit. A general rule to apply is that, where a component has an effect on one or more circuits, it should be allocated to the first circuit in which it has an effect, e.g. an H.T. dropping resistor feeding a chain of three circuits should be shown in the first circuit in the chain. Components which cannot be dealt with by this general rule will either require the use of a special technique (e.g. extract the succeeding valve or disconnect a lead) or will have to be marked as components likely to affect the output of more than one circuit.

Chain Diagrams

22. Circuit diagrams are grouped together to form chain diagrams. Each chain diagram should preferably refer to only one major function in the equipment, e.g. the transmitter chain would be a chain common to most primary radars.

23. In chain diagrams it is usually convenient to show circuits as boxes, and, if this is done, all the inputs and outputs of the boxes, excluding power supplies, should be shown on the chain diagram. Power supplies would normally be illustrated in a chain of their own.

24. As with circuit diagrams, data flow should be in one direction only. All inputs should be illustrated on one side of the diagram and all outputs on the other. If data flow principles are used the main signal path will, as near as possible, be a series of circuits along the horizontal axis of the diagram.

25. Examples of Chain Diagrams are shown in Figure 3, "Orange Putter Chain II", and Figure 4, "Green Satin Chain II". In examining these chain diagrams, the following points should be noted. Firstly, Figure 3 "Orange Putter Chain II":-

(a) The general direction of data flow is from left to right.

(b) The outputs, which appear on the right hand side of the diagram, list the functions of the chain.

(c) To avoid writing each circuit title in the appropriate box, only the circuit numbers are shown on the chain diagram. If required the circuit title can be found by referring to the actual circuit diagram or to the list of circuit numbers and titles which, in this booklet, is shown as Appendix 'A'.

(d) Test points are shown as white numbers in black circles. They normally refer to voltages or waveforms at a specific point, but in some circumstances they refer to a component which can be checked in several ways or conditions e.g. relay contacts and switches. (Lists of checkpoint data are not included in the booklet).

(e) All inputs to the chain appear on the left hand side of the diagram. The monitor 102 pulse generator is part of a piece of second line test equipment and, because the diagram is drawn for a second line bench rig, it appears as an input. All external controls have also been shown as signal inputs on this diagram as they have a direct effect on one or more of the chain outputs.

(f) A pre-pulse input appears at several points on the diagram and the pre-pulse circuit is apparently located in several different chassis. This is because all of these chassis appear in circuit 1. If a fault were suspected in any of the pre-pulse inputs reference to the pre-pulse circuit diagram would be necessary to see the relationship between the inputs.

(g) The Co-incidence circuit (circuit 16) of Figure 2 is shown as a circuit box in the chain diagram.

26. Secondly, the following points should be noted when examining Figure 4, "Green Satin Chain II". (The reproduction of this diagram is not satisfactory, and test point numbering and certain other information are obscured).

(a) The general direction of data flow is from left to right.

(b) As with the Orange Putter diagram, the outputs of the chain appear on the right hand side of the diagram and list the functions illustrated in it.

(c) Second line test equipments (Performance Testers 4332 and 4333) are shown connected as they would be in a second line bench rig.

(d) A list of Green Satin circuit diagrams, including those illustrated in Chain II, is given at Appendix 'B'.

Block Diagrams

27. Just as a chain diagram shows the inter-relationship of the circuits within it, so a block diagram should show the inter-relationship of the chains within the equipment. With equipments of average complexity (e.g. those from which the examples in this booklet have been taken, namely Orange Putter and Green Satin), only one block diagram is necessary, but with larger equipments, or completely integrated systems (TSR 2, Lightning 2, etc.) it may be found necessary to have more than one block diagram and to provide a system diagram.

path should be clearly marked in a different manner to the forward path, e.g. with a double arrow thus 

(c) Overlap of signal path should be avoided wherever possible.

(d) All of the information required to fault find in the diagram should be available on it or with it. All plugs and sockets in the path of the signal should be labelled in a standard way, e.g. plug number above or to the left of a lead and wire number or letter below or to the right of a lead.

(e) Physical boundaries of all types should be shown on the diagrams, but these may be of any shape and in any position to fit in with the data flow pattern. If necessary a chassis can be shown in several different places. Light colouring or shading can be used to assist the recognition of particular chassis, providing it does not obscure the data flow path.

(f) Arrows should be drawn to indicate the data flow path through a diagram. An arrow into a circuit will therefore indicate that the lead carries a signal which will modify the output of the circuit and an arrow from a circuit will indicate that the lead carries a signal which is modified by all of the inputs to the circuit.

(g) All circuits within a chain (i.e. not at the beginning or end of it) must have all their signal inputs and outputs shown. Circuits at the input or output of a chain need only show the input (s) or output (s) relevant to that chain.

(h) No power supply leads should be considered as carrying a signal. Therefore, when shown on a diagram illustrating true signal flow, no arrows should be drawn on them. Where power supplies only are illustrated then the diagram should be treated merely as a distribution diagram, and arrows on such a diagram will indicate which circuits are the source of supply and which are receiving supplies. Only in special circumstances should an arrow be used to indicate current flow. Examples of Power Supply diagrams are given in Figure 7(a) Green Satin Power Supply Chain, and Figure 7(b) Orange Putter Power Supply Chain.

(j) Accessible test points are to be clearly numbered and the normal state signal parameters should be readily available. It is particularly important to have test points available at the inputs and outputs of circuits and chains.

(k) Voltages which are variable by means of pre-set controls are normally only varied at the initial setting up of the equipment and therefore should not be considered as signal voltages. Voltages variable by external controls, which have a direct effect on the equipment output, should be considered as signal voltages.

(l) Circuit diagrams should have a standard layout and a suggested form for this is shown on Figure 2(b). Circuit number, circuit title, and the chain in which the circuit appears are indicated along the top of the diagram. There will only be one chain diagram which illustrates all the inputs and outputs of a particular circuit, and it is this chain number which should be illustrated. In the case where a circuit is never shown with all inputs and outputs present then there should be no chain number on the circuit diagram. Controls, and the number of the circuit in which the heater connections are illustrated, are shown at the bottom of the diagram. All information required to fault find in the circuit should be supplied with it.

(m) Small portions of circuits may be drawn inside a circuit box in a chain diagram where it is considered that this provides additional useful information (e.g. if two outputs are joined by a resistor, or an output is joined to a test point).

THE USE OF DATA FLOW DIAGRAMS FOR FAULT FINDING

34. If data flow diagrams are drawn according to the above rules it is possible to use them as an aid to the application of logical fault finding techniques. This section gives examples of how the diagrams can be used to this end, but it is not intended to give a comprehensive description of all the fault finding techniques which can be applied.

35. The first requirement when tackling a fault is to obtain a complete symptom pattern and to make logical deductions about the source of a fault by noting which outputs are correct and which incorrect.

36. Figure 8, "Car Electrical System" illustrates how this first fault finding stage can be helped by using a data flow diagram. Figure 8(a) shows a wiring diagram as illustrated in a car workshop manual. The parallel wires, many cross-overs and almost random positioning of the components (though some attempt has been made to put them in positions suited to their physical location) makes it difficult to follow. In contrast Figure 8(b) with no cross-overs and a clear indication of the inputs and outputs is easier to follow.

37. As an example of fault finding in this circuit, suppose that the horn is not functioning and that it is already known that the car starts and the dynamo charges correctly. What is a logical test to narrow down the area in which the fault might be, assuming that only one fault is present?

38. The symptoms given tell us that there is a voltage at point A on the control box. Therefore, the fault lies between A on the control box and the horn earthing point. It can be seen that the most logical check is to turn on the interior lamp. If this is not working the fault is between point A on the control box and point A2 on the fuse i.e. the area common to the light and horn. If the interior lamp is working, the fault lies between point A2 on the fuse and the horn earthing point. Similar deductions can be made for other fault conditions and the usefulness of each diagram for finding the faults can be compared.

39. It should be noted that, in the example illustrated, care has been taken to ensure that the information presented in the data flow diagram is exactly the same as that presented in the conventional diagram. One feature of the car diagram which is extremely useful when fault finding is that actual connection points for the wires are shown. This feature is preserved in the data flow diagram.

40. In Figure 8(b) arrows are drawn to illustrate data flow with the system operating in both of its common conditions (battery charging and battery not charging). Also in the simpler diagram, shown as an example, data flow corresponds to electron flow.

The Use of a Functional Check

41. In a more complex system it is not easy to obtain all the symptoms directly, and it becomes necessary to do a number of checks (visual and aural) and adjustments to obtain the complete symptom pattern. Procedures currently used for checking out an equipment do not check function-by- function in a detailed logical manner suitable for use with data flow diagrams. In order to use diagrams which had been drawn for Orange Putter, the equipment's functional check was rewritten in a manner which fitted the data flow requirements.

42. This new type of functional check, which, it is suggested, should be used with all data flow diagrams, is designed to check each function of the equipment in turn, chain by chain, noting the outputs which should be obtained and the effect on the outputs of varying the controls. At the end of the check all outputs of the equipment will have been checked and all controls varied. Any fault symptom which is apparent to an operator of the equipment, should therefore have been found and noted.

43. If the functional check is written in a logical manner it is not always necessary to complete it before starting to fault find in a particular chain or circuit. Having reached an incorrect output it is often possible, bearing in mind the result of previous checks, to go straight to a circuit. It should be noted that a functional check of this type does not check for out-of-tolerance readings, unless they affect an output, and does not ensure that all parts of the equipment are working at maximum efficiency. A check of the type contained in the Volume 4 of an A.P. is at the moment still required for this purpose.

44. Appendix 'C' contains an extract from a functional check of the type mentioned in the above paragraph. The check is specifically written for a particular type of trainee and is also specific to an R.A.F. Yatesbury Orange Putter bench set. For these reasons it is probably more detailed than that which would be required for a fitter. Also, in operational circumstances, the difference in the requirements of 1st and 2nd line servicing would make it necessary to have two checks, one for the first line fitter, and one for the second line fitter.

The Split Half Technique

45. Having noted the complete symptom pattern and made any possible deductions from it, further tests must be made to narrow down still further the area in which the fault has occurred. The simplest technique which can be applied to data flow diagrams is the split half technique. This simply means that when testing a series of components (or valve stages within a circuit, or circuits within a chain) by signal tracing, knowing that the input is correct and the output incorrect, the quickest route to the faulty component is to test at the centre of the series. A correct result means that the fault is to the right of the test point and an incorrect result means that the faulty component is to the left of the test point. The remaining series of components is again checked at the centre and the process is continued until the faulty component is isolated.

46. Figure 9, "Theoretical Chain Diagram" shows a simple chain diagram. It could also represent a block diagram, circuit diagram or even interconnections of block diagrams to form an equipment, and the following arguments would apply in any of these cases. Let us suppose that there is a fault in one box such that outputs W, X and Z are correct and output Y is incorrect. The first deduction, looking at the symptom pattern, is that the signal at point A must be correct. Using the split half technique it is clear that the next check should be at point B, and a second test will then isolate the faulty box.

47. Practical considerations are often such that it is not always possible to check at the ideal point; circuits may be in a sealed container, for instance. Also, what appears as a short inter-connecting lead in the above diagram (e.g. A to C) may be a long lead passing through many connections and other chassis. Although these factors complicate the diagram, the split half technique can still be used if all accessible test points are marked on the chain. In these circumstances the first check is made at the centre test point and so on, the only reason for not following the rules being the relative accessibility of the test points or complexity of the tests to be made. Cable runs can themselves be checked using the split half technique and indeed checking is done on long runs of electricity power distribution cables in this manner.

48. Figure 10 shows an extract from the Orange Putter Chain II diagram. Taking this part of the chain in isolation let us assume that the - 150V supply is known to be correct, but test point 13 gives an incorrect reading. First, SW1b should be operated to expand the symptom. Let us assume that, when the switch is in the A position, a correct output is obtained from point X. The fault must now be between E of the switch and test point 13. Test point 12 is the only readily accessible test point, so this should be checked next. A description of how to test and what to expect will be given with the diagram. Suppose that the result of the test is an incorrect reading. The lead between E and SK1800/K should be checked next and using the split half rule on this short section, PL1701/B is the best place to test. A further test at PL1900/B or PL1700/K will then resolve the fault to a particular cable length or component.

49. Expanding the symptom pattern and applying the split half technique whenever possible, are therefore two of the basic techniques of fault finding which can easily be used with data flow diagrams. It is often argued that these simple techniques cannot be applied to the complex circuitry normally encountered in service equipment. Brief mention will therefore be made of a common case where a special technique has to be used to apply the rules, that of the feedback loop.

The Treatment of Feedback Loops

50. In general feedback is of two types, namely, modifying feedback and sustaining feedback. Modifying feedback exists when the output of a device is fed back to modify the input, but the input does not rely on the feedback to maintain it. Common examples are A.G.C. systems and linearising feedback loops. With this type of feedback it is possible to disconnect the feedback loop and note the effect on the output; this requires that the output characteristics without feedback are known. Disconnection of the feedback loop can therefore be used to resolve the modifying feedback case.

51. Sustaining feedback exists where the feedback loop is essential for producing an output; if the feedback is disconnected, the circuit or chain stops functioning completely. Common examples are oscillatory circuits and types of servo loop. With sustaining feedback therefore, it is not possible to disconnect the feedback path, as the output will completely disappear. One solution to this problem is to ensure that the whole circuitry affected by the feedback is in one of the smallest units of the equipment, and that, when the unit has been isolated, voltage or resistance checks can be made to resolve the faulty component. If this is not possible each case will have to be treated separately and techniques for resolving the problem, such as providing an alternative source to the signal feedback, will have to be noted on the appropriate diagrams. The Orange Putter A.G.C. loop could not be disconnected, but waveform and voltage measurements at appropriate points gave sufficient information to resolve the faulty circuit.

52. It should be emphasised that the fault finding techniques referred to can only be applied if the necessary test points are available and clearly marked, and all the necessary test data is supplied. It is essential therefore, that this information is given on or with data flow diagrams. Even if the equipment is not designed to give adequate test points, it is still possible (particularly at 2nd line) to find accessible points, take measurements at them, and record them as test points. This has been done, to some extent, for Orange Putter diagrams.

ADVANTAGES OF THE DATA FLOW APPROACH TO FAULT FINDING

53. It is considered that data flow diagrams, used with a logical fault finding technique and adequate support information can satisfy the requirements of a good fault finding method. Other advantages of using data flow diagrams are that:-

(a) The diagrams could be drawn at a very early stage in the life of an equipment (certainly before it came into service) and problems, such as those of splitting up the circuits and resolving feedback loops, could be tackled at this stage. Thus, before an equipment was introduced, a complete fault finding guide could be produced. This would alleviate problems caused by faults on new equipments not having been met by the servicing personnel.

(b) The diagrams may provide a logical structure for teaching an equipment.

54. Conventional diagrams do not have these advantages. Possibly the fault is that, although an equipment is originally thought of in terms of data flow, the presentation of information is orientated about a physical box-by-box description and detailed drawing office specifications.

Other Fault Finding Methods

55. Mention should be made of two other methods which are commonly used to find faults, firstly, the method of replacing units until the fault is corrected (replacement method), and secondly, the method of keeping a library of faults and associating fault symptoms directly with a faulty part of the equipment (probability method). There is certainly a place for both of these methods, but they have serious disadvantages when used as a major fault finding technique. The replacement method seldom enables a fault to be resolved conclusively, and it requires complete spares backing at all levels. If boxes are large, a change does not get one very far in isolating the faulty component and if they are small, it is a long and tedious process to change them all.

56. The probability method cannot be used on new equipments, it is inaccurate and leaves the fault finder stranded if it fails. Normally, if faults do occur regularly they are the subject of a modification and therefore any library of faults would be large and varied, rather than small and accurate. Although the method has these serious disadvantages there is no doubt that an accurate record of fault symptoms and their related causes, obtained from experience on the equipment, can be used to supplement basic fault finding techniques. Changing a suspect box or component for a known serviceable one is a useful artifice, when used sensibly and in moderation.

FURTHER EXAMPLES OF DATA FLOW DIAGRAMS

57. Figures 1 to 8 have already given some examples of data flow diagrams and, as further examples, figures 11 and 12 compare conventional A.P. circuit diagrams (TOP) with their data flow equivalent (BOTTOM). The most important feature to note is that the layout is functional and, as far as possible, follows the rules laid down in paragraph 33. (Test point and additional data are not given with the diagrams in the examples shown).

58. In drawing the diagrams in this booklet several attempts were made before the final diagram was obtained; even so there is still room for improvement in some of the diagrams. Figures 13 to 15 show some of the stages used by the writer to arrive at figure 16. Figure 13 is the circuit as it appears in a portion of the A.P. circuit diagram. The first problem is to separate the circuit from those components which belong to other circuits. This has been done in Figure 14. A first attempt at redrawing the circuit in data flow terms is shown in Figure 15,

and the latest attempt is shown at Figure 16. In figure 16 the anode and cathode connections of V13 have been reversed, this is an error as the diagram should remain electrically the same as the original.

CONCLUSION

59. This booklet has outlined some work done in the preparation and use of data flow diagrams. The work has been confined to two moderately complex equipments, Orange Putter and Green Satin, and it is obvious that only a few of the many problems which exist have been dealt with. Nevertheless, it is thought that the principles involved could be applied generally to all electronic equipment.

60. The Army (R.E.M.E.) has produced detailed drawing office specifications for circuit diagrams, which substantially agree with the principles outlined in this booklet.

61. A vast amount of work has been done in the field of fault finding techniques, much of it in America. The references list some of the reports available at H.Q. Technical Training Command. All references can be obtained on loan by application through normal station administrative channels.

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American Institute for Research, Report No. MRL-TDR-62-42.

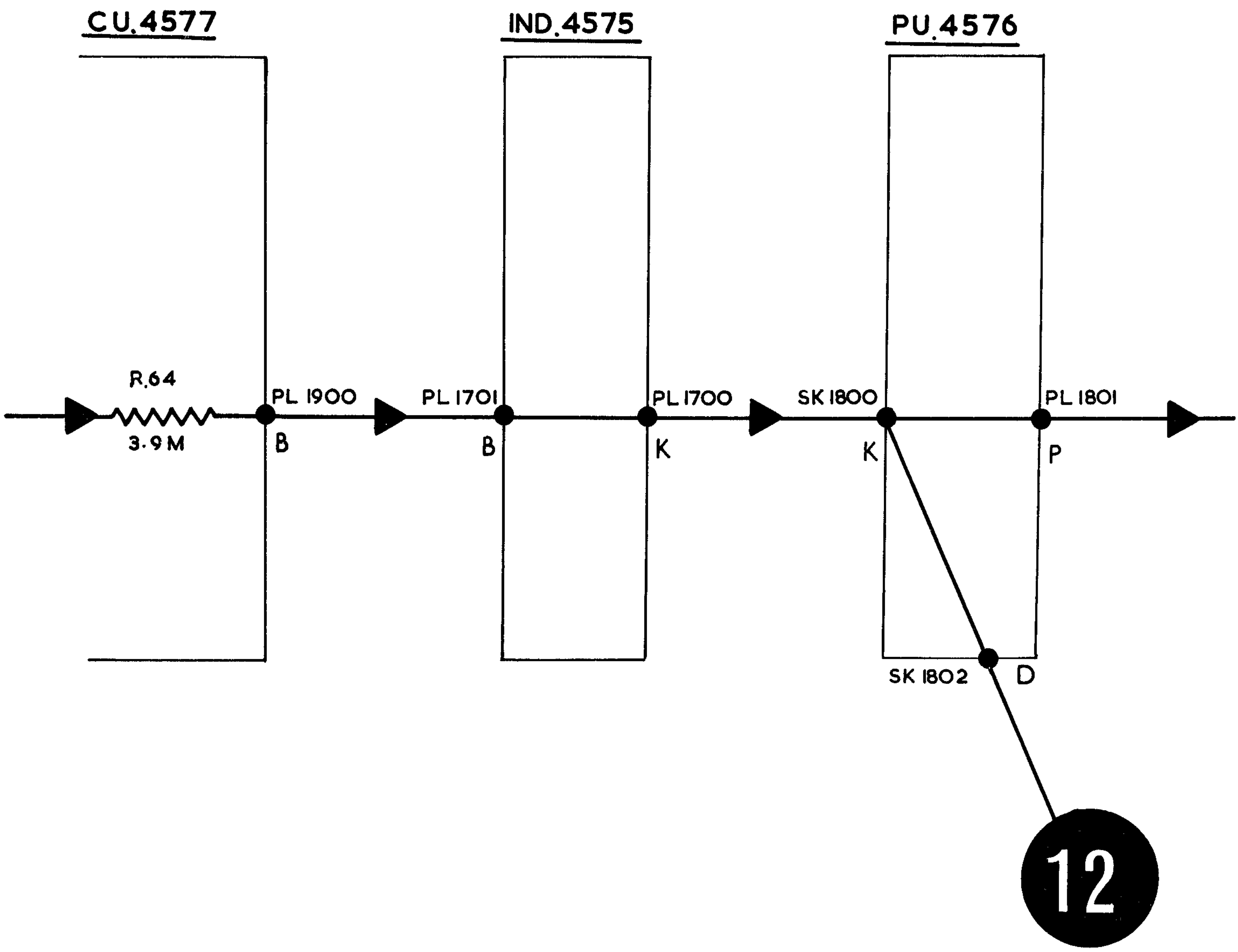


Figure 1. Extract From An Orange Putter Chain Diagram (1).

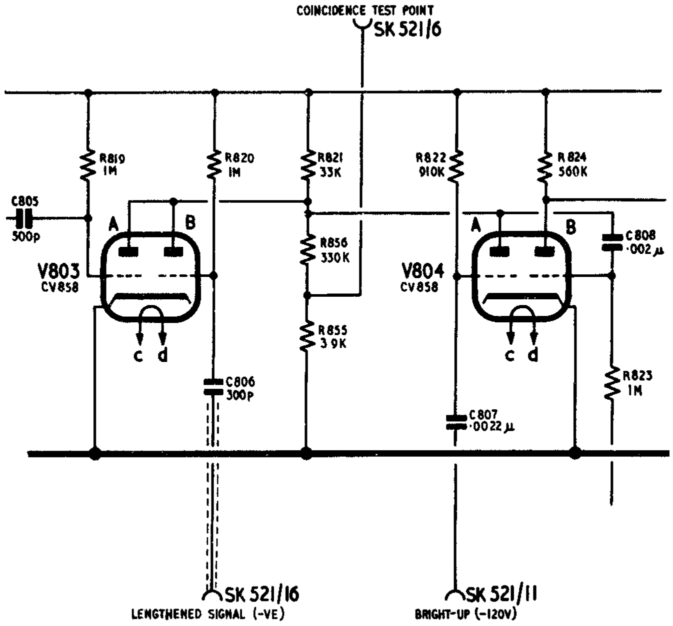


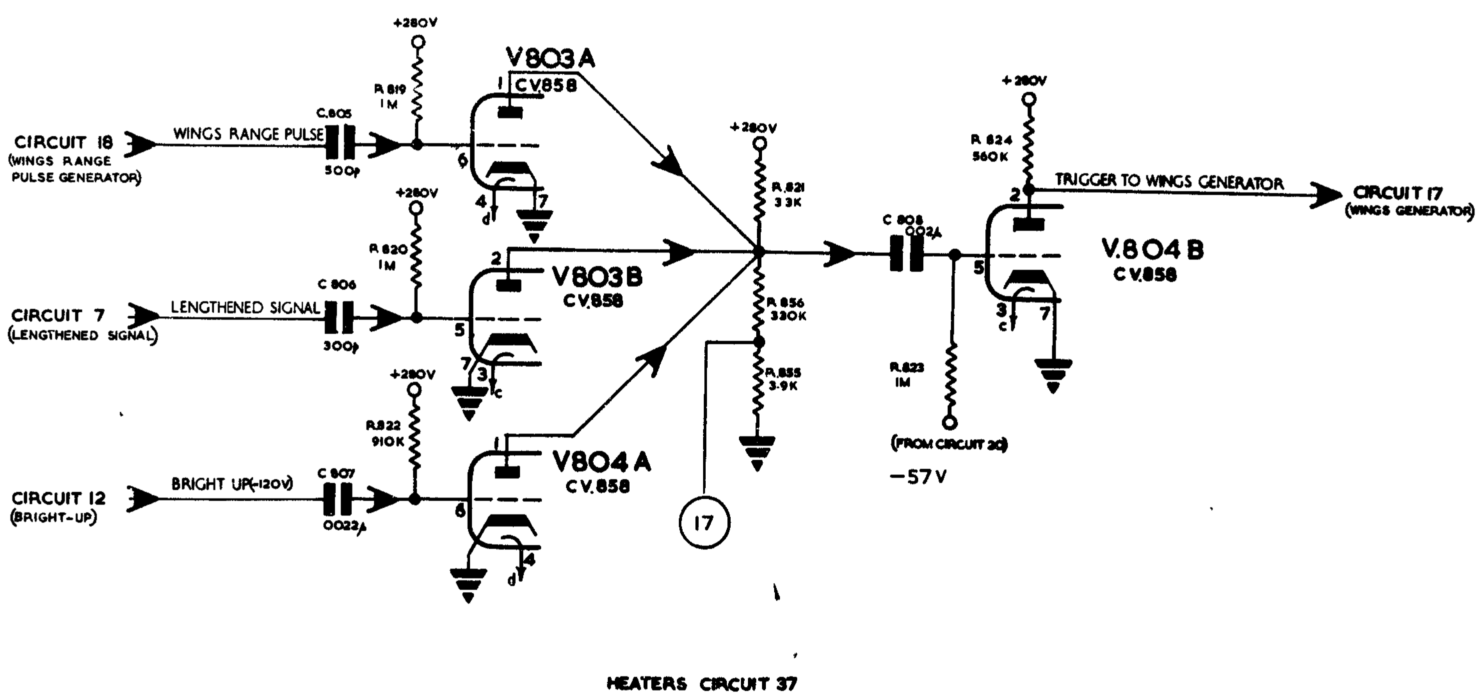
Figure 2(a).

Figure 2(b).

CIRCUIT NO16

CO-INCIDENCE
(CHASSIS 3)

II



CONTROLS

Figure 2 Orange Putter Co-incidence Circuit

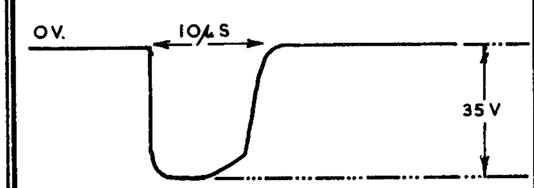
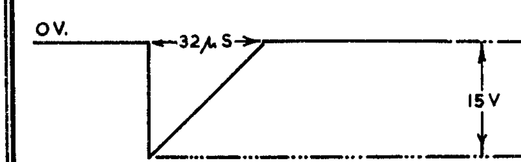
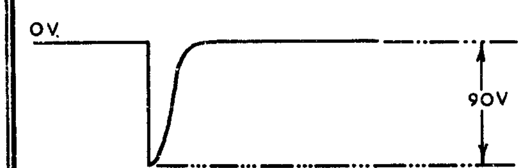
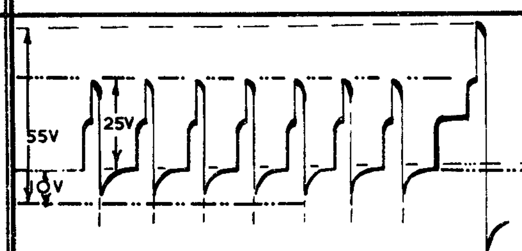
WAVEFORM AT	Y GAIN	METER MULTIPLIER	T.B SELECTOR	T.B RANGE	TRIG SELECTOR	TR.G	WINDOW		*Waveform*	METER READING
V.803A grid (pin no. 6)	X 6	10	TRIG	30μS	P P	+	+	SIG NO. AT 8. WITHIN W. RANGE, TX "ON"		0·25
V.803 B grid (pin no. 5)	X 6	20	TRIG	1 ms.	P P	+	+	SIG NO. AT 8 WITHIN W RANGE. TX "ON"		0.65
V. 804 A grid (pin no. 6)	X 2	20	TRIG	10 ms.	L.S +	+	+	SIG NO. AT 8 WITHIN W RANGE TX "ON"		0.35
V. 803 A AND V 803 B anodes (pins no 1 and 2) V 804 A anode (pin no 1.)	X 2	10	TRIG	10 ms	L.S +	+	+	SIG NO. AT 8 WITHIN W RANGE TX "ON"		0.6

Figure 2 (c).

Circuit 16.

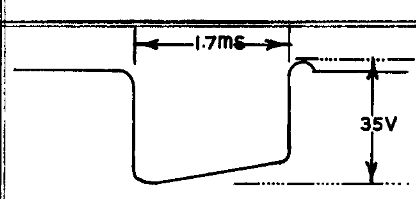
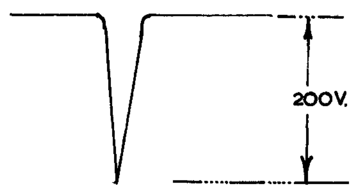
WAVEFORM AT	Y GAIN	METER MULTIPLIER	T B SELECTOR	T B RANGE.	TRIG SELECTOR	TRIG AMP	WINDOW	MEAN LEVEL		Waveform	METER READING
V. 804 B ANODE PIN (2) WITH V.805 IN CIRCUIT	X 2	5	TRIG	10mS	LS +	+	+	35V	SIG NO. 8. TX, 'ON'		.7
V 804 B ANODE PIN (2) WITHOUT V.805, IN CIRCUIT.	X0.6	50	TRIG	10mS	LS +	+	+	0V	SIG NO. 8. TX, 'ON'		.4

Figure 2 D.

CIRCUIT 16. COINCIDENCE

RESISTANCE MEASUREMENTS

Valve	Pin Nos. 1	2	3	4	5	6	7
	Resistance to earth with valve removed						
V 804	50K	570K	133K	133K	1.1M	920K	●
V 803	50K	50K	133K	133K	1.05M	1.05M	0
	D.C. resistance to + 280V supply						
V 803	30K	30K	160K	160K	1.0M	1.0M	27K
V 804	30K	560K	160K	160K	1.1M	910K	27K
	D.C. resistance to-57V bias line						
V 804	–	–	–	–	1.0M	–	–

Resistance across capacitors

C805 = 1M C806 = 1M C807 = 900K C808 = 1.3M

Which components to unhook

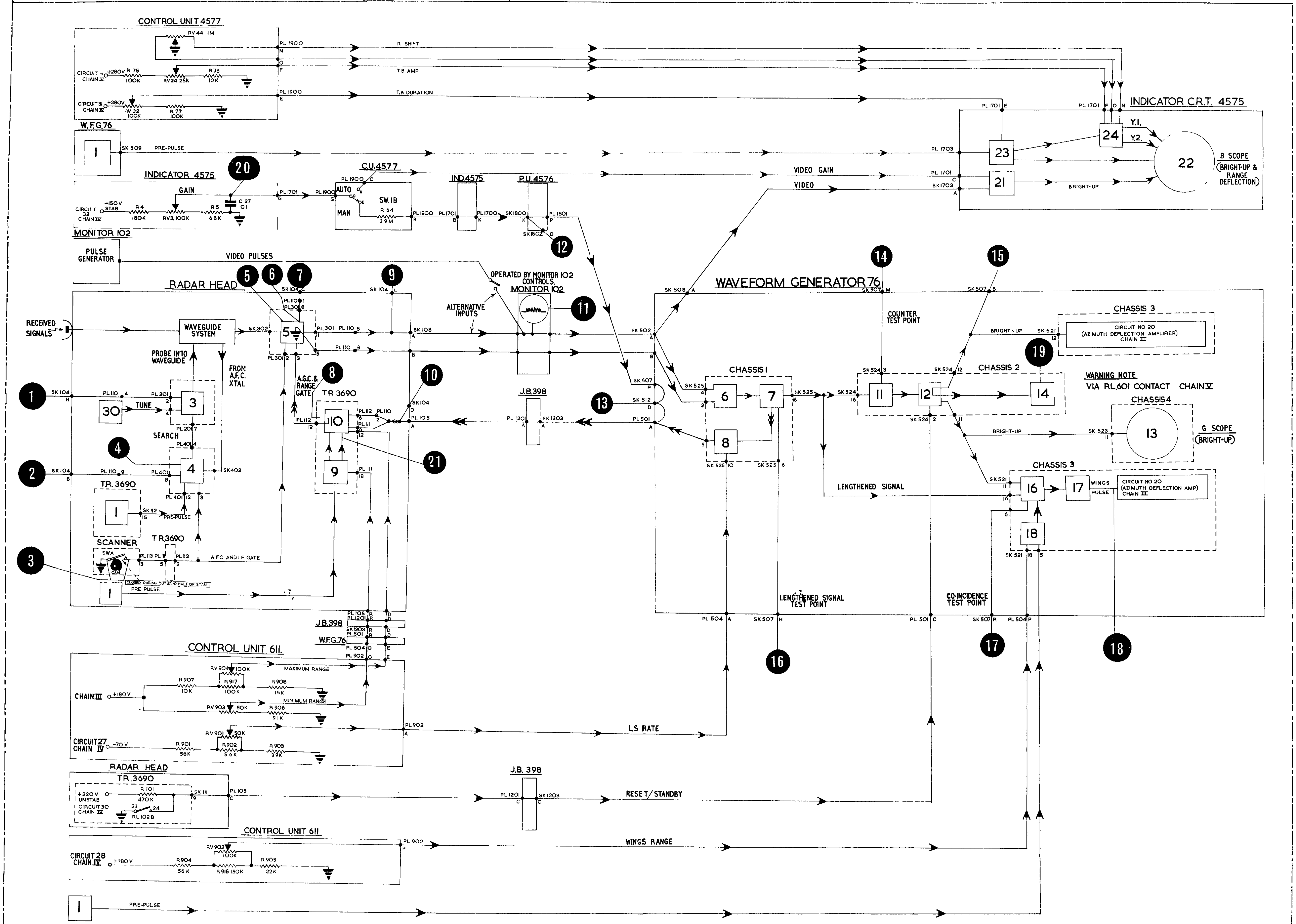
R 819 Measure directly
R 820 " "
R 822 " "
R 824 " "
R 823 " "
R 821) Unhook any end
R 856)
R 855)

VOLTAGE MEASUREMENTS

V 803A Grid (6) + 0.25 Volts d.c.
V 803B Grid (5) + 0.25 Volts d.c.
V 804A Grid (6) + 0.25 Volts d.c.
V 804B Grid (5) – 50 Volts d.c.
V 803A Anode (1))
V 803B Anode (2)) Common + 20 Volts d.c.
V 804A Anode (1))

FIGURE 2(e)

CHAIN II RECEIVED SIGNAL CHAIN



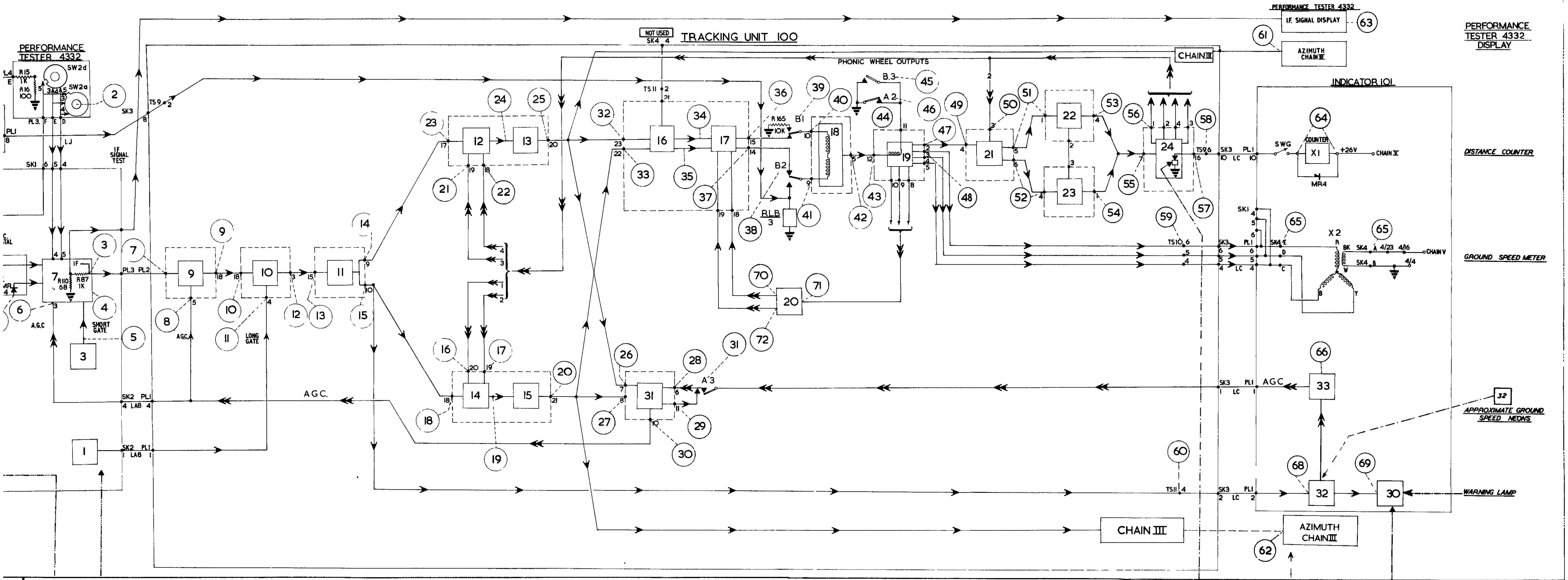
CONTROLS

RV3	GAIN	R.V.901	L.S. RATE	S.W.A.	CAM OPERATED BY THE SCANNER CHAIN V
RV24	TB AMP	R.V.902	WINGS RANGE	SWIB	AUTO/MANUAL SWITCH B SCOPE (SW.IA. CHAIN IV)
RV32	TB DURATION	RV903	MAXIMUM RANGE	RL.102B	OPERATED BY E.H.T RESET/STANDBY SWITCH CHAIN IV
RV44	R SHIFT	RV.904	MINIMUM RANGE		(RL.102B CLOSED ON RESET)

Research Section Drawing HQT7C (O.P.2)

Figure 3. ORANGE PUTTER CHAIN II

) II RECEIVED SIGNAL CHAIN GREEN SATIN



.S INCHING SWITCH (SPEED) INDICATOR 101 SELECT XTAL PT 4332 SWITCH OPERATED BY PHONIC WHEEL MOTOR COUNTER ON/OFF SWITCH (SW.G) SIGNAL/MEMORY SWITCH

Research Section Drawing G.S. H.Q.T.T.C.

Figure 4. *GREEN SATIN CHAIN II*

Figure 5(a) A.R.I. 5800: BLOCK DIAGRAM

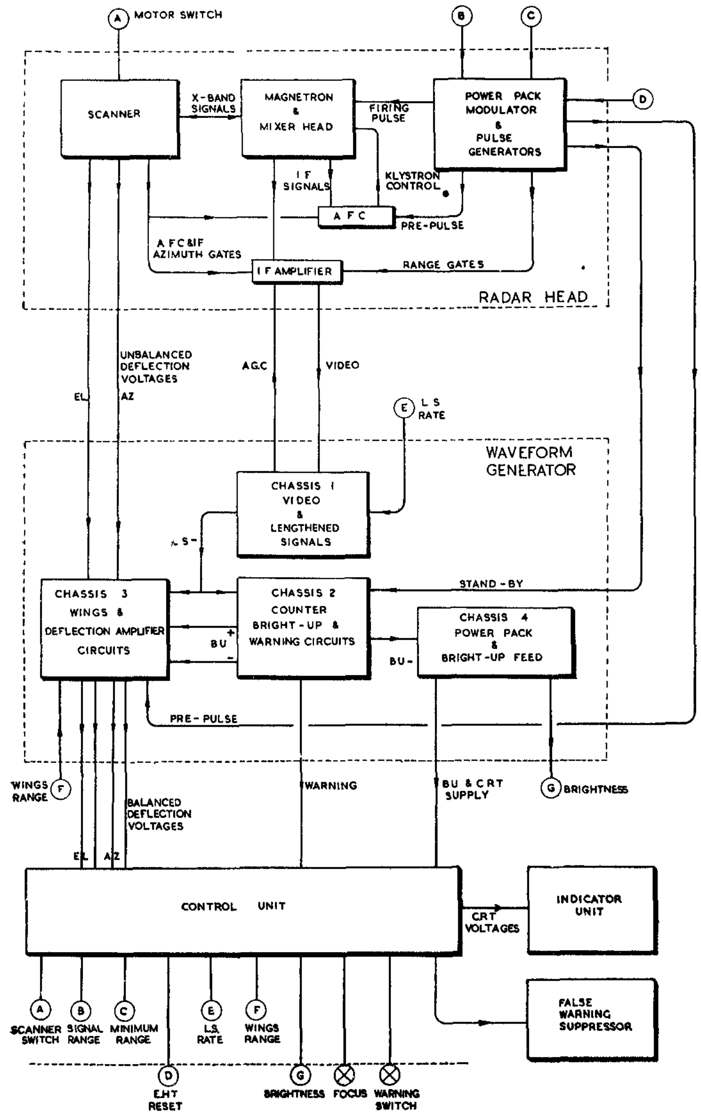
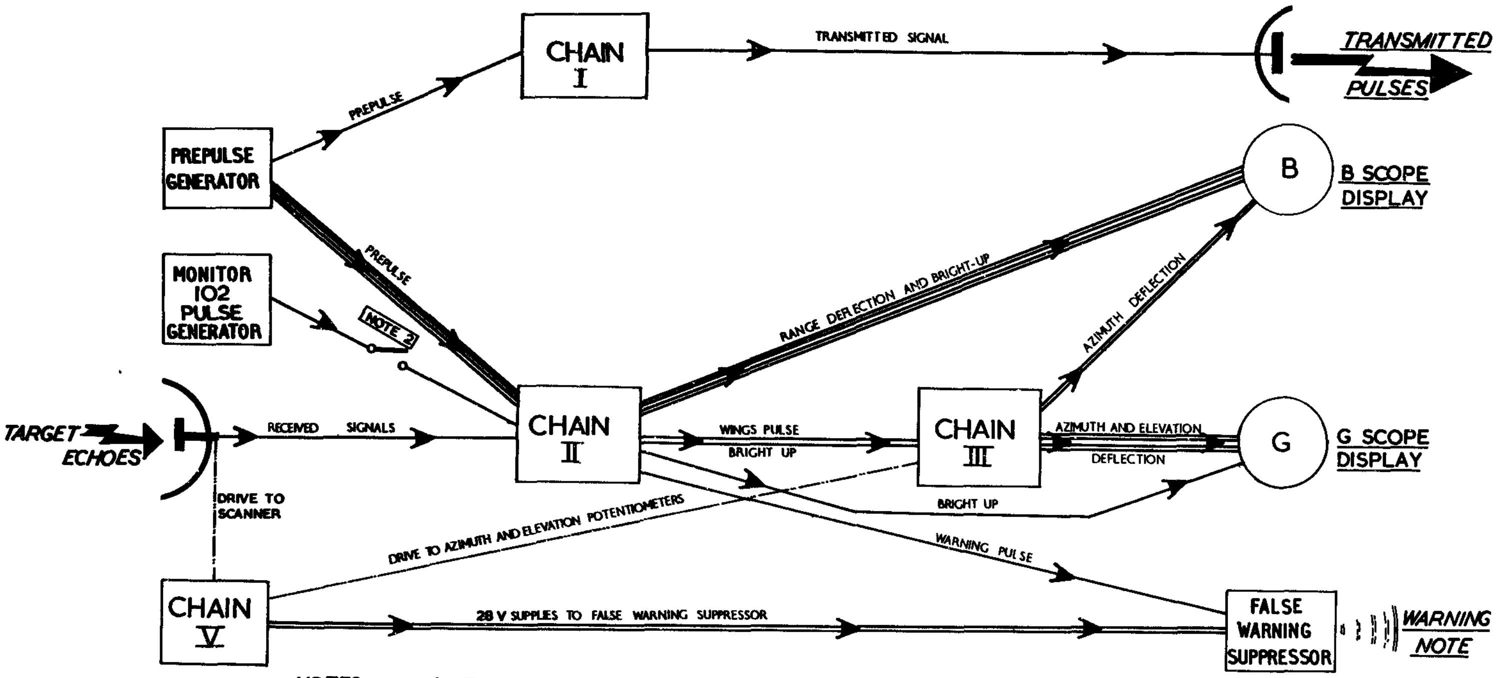


Fig. 5(b). ORANGE PUTTER BLOCK DIAGRAM



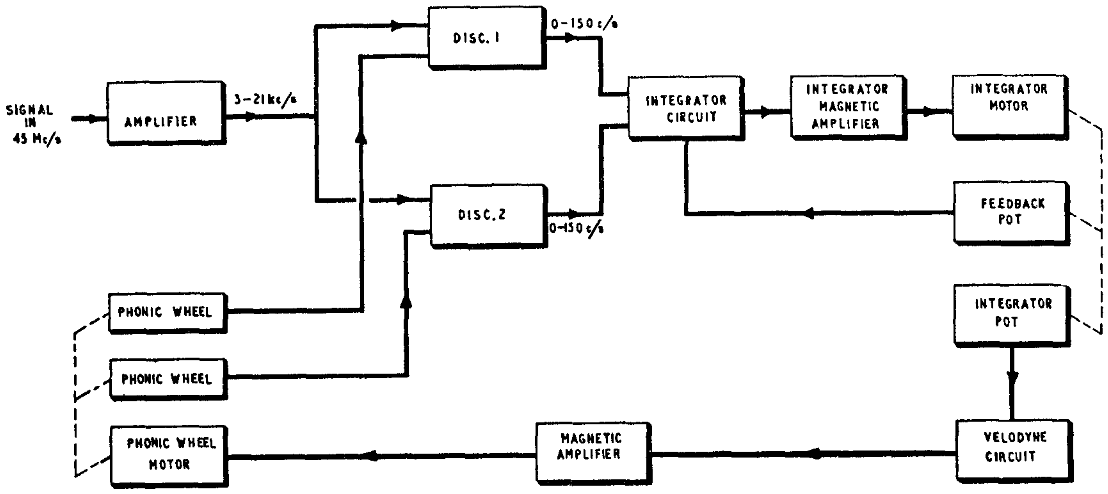
NOTES —:

1. The interconnections are duplicated on the individual Chain Diagrams
2. The MONITOR 102 provides a controlled stream of pulses as an alternative to the received signal pulses. The switch represents the effect of the Monitor Controls. The settings of which are noted in the functional check.
3. All Circuits and Chains are supplied with Power as illustrated in CHAIN IV

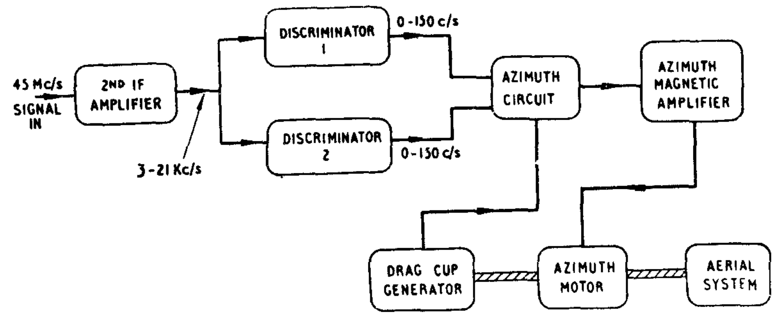
Research Section Headquarters Technical Training Command

FIGURE 5. Orange Putter Block Diagrams.

Figure 6(a).

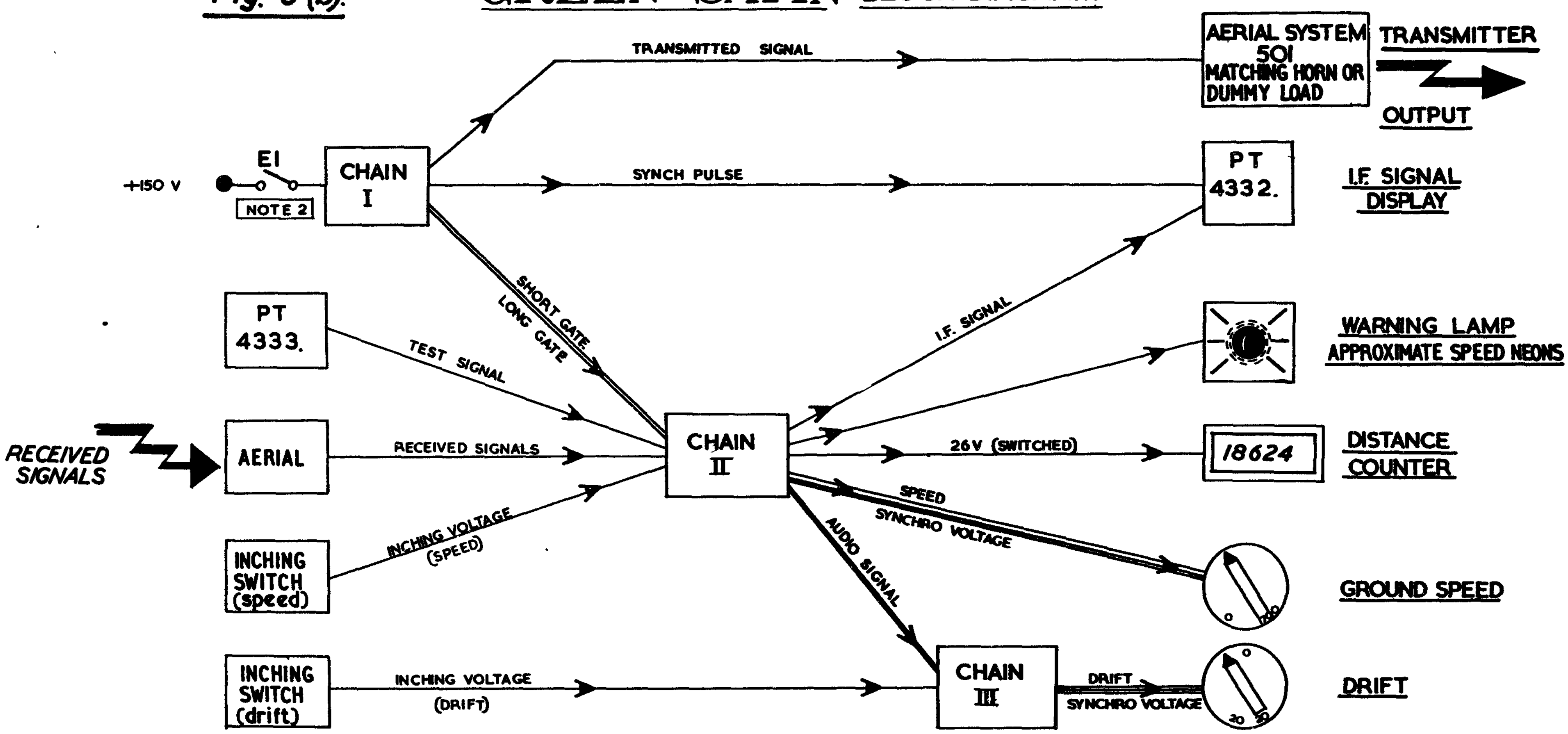


Ground Speed Block Diagram.



Drift Angle Block Diagram

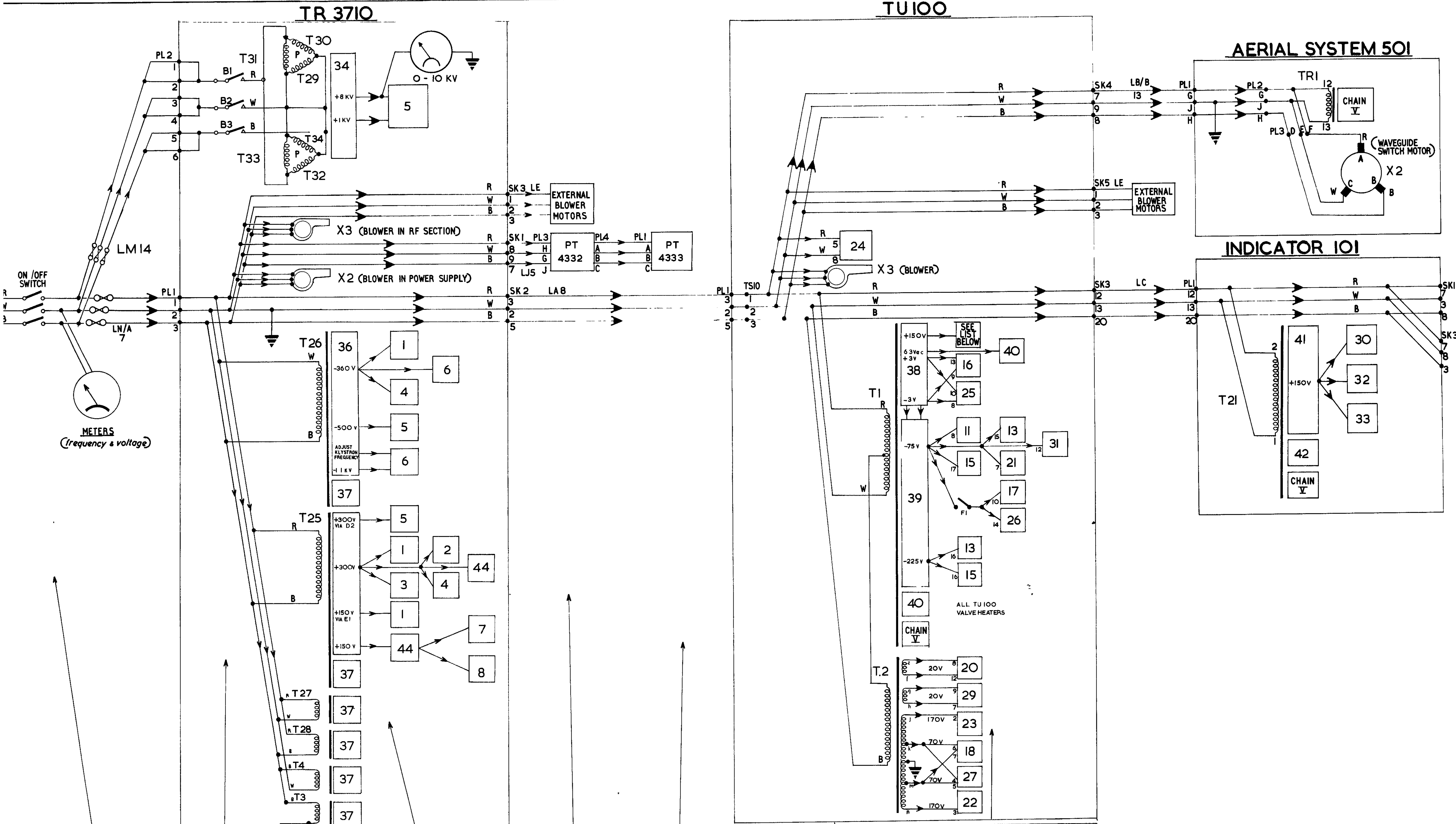
Fig. 6(b). **GREEN SATIN**- BLOCK DIAGRAM



NOTES-1. The Interconnections are duplicated in the individual Chain Diagrams
2. CHAIN I is triggered by E1 which closes once every half a second see Cct.44
3. All Chains and Circuits are supplied with Power as illustrated in CHAINS IV & V

FIGURE 6. GREEN SATIN BLOCK DIAGRAMS

CHAIN IV POWER SUPPLY CHAIN



CCT NO	CIRCUIT BOARD	PIN NO	CCT NO	CIRCUIT BOARD	PIN NO	CCT NO	CIRCUIT BOARD	PIN NO
9	2ND. I F AMP	6	14	DISC.2	15	26	AZIMUTH	15
10	AUDIO AMP	6	15	DISC.2	15	30	SIGNAL/NOISE	13
11	PRE-AMP	7	17	INTEG	11	31	SIGNAL/NOISE	13
12	DISC.1	14	19	INTEG GEAR BX	1	39		DIRECT
13	DISC.1	14	21	PW VELODYNE				

CIRCUITS SUPPLIED WITH 150v FROM CIRCUIT NO.38.

'ROLS	ON /OFF SWITCH	CONTACTS B1, B2, & B3. (SEE CCT 44)	CONTACT B4 (SEE CCT 44)	ADJUST KLYSTRON FREQUENCY (PRESET)	CONTACTS D2 E1 (SEE CCT 44)	PT 4332 ON/OFF SWITCH AND RED LAMP (W & B PHASES ONLY)	PT 4333 ON/OFF SWITCH AND RED LAMP	CONTACT F.1. (SEE.........)

Research Section H.Q.T.T.C. (Green Satin)

Figure 7(a) *GREEN SATIN POWER SUPPLY CHAIN*

POWER SUPPLY CHAIN

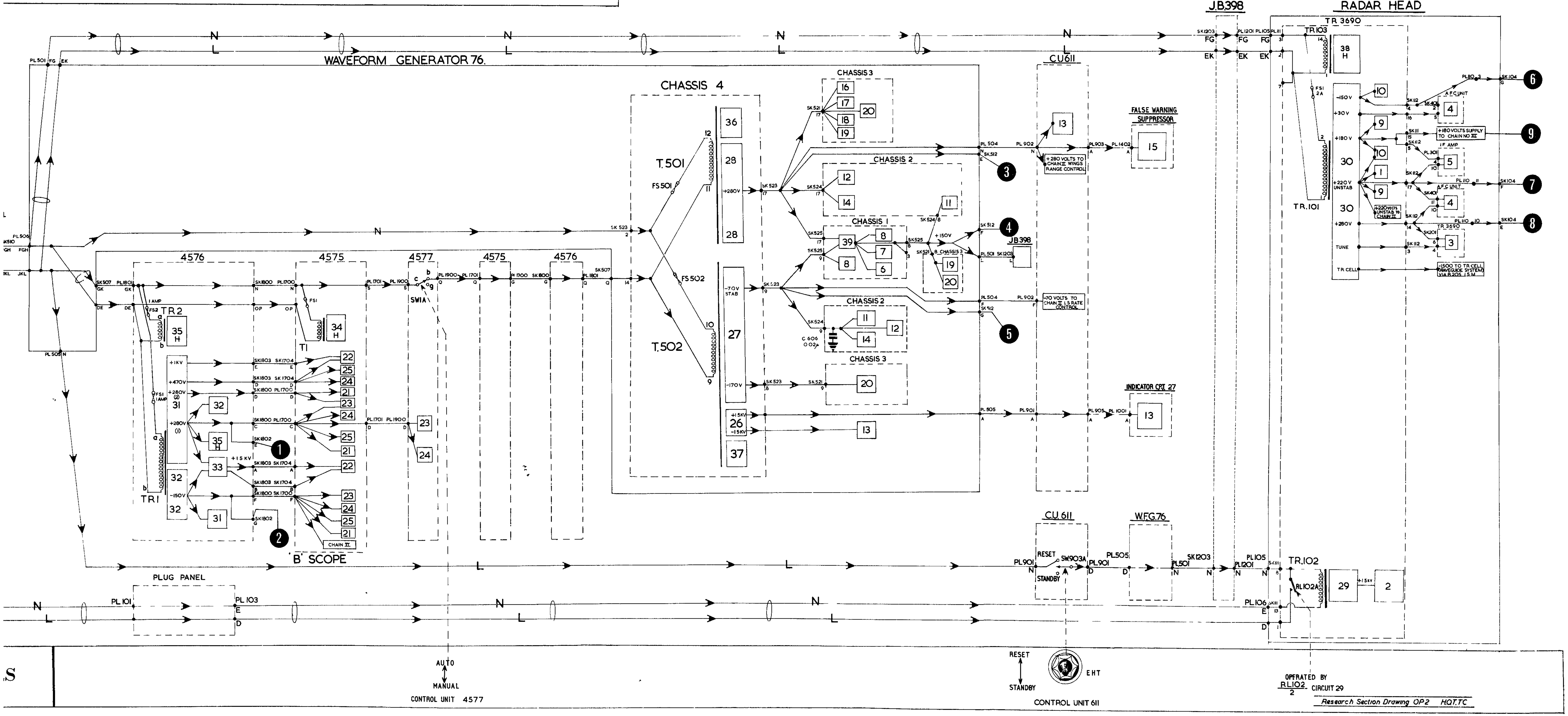
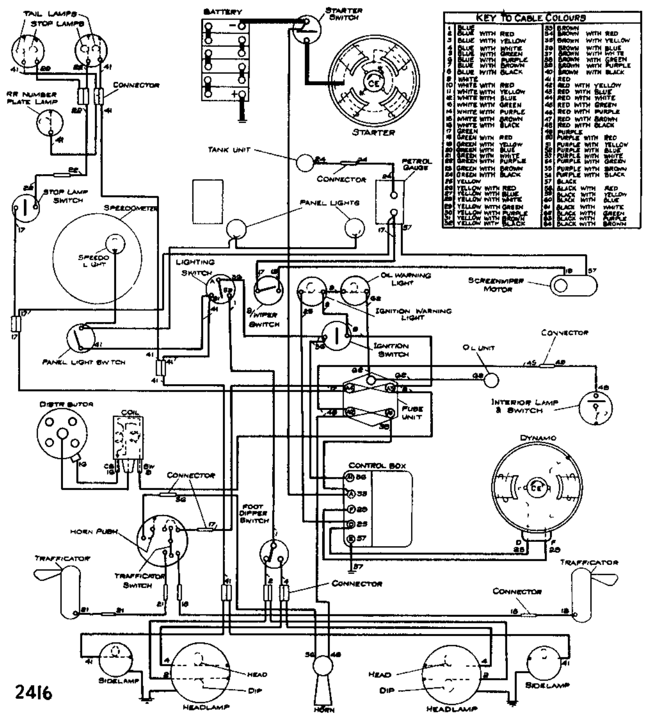


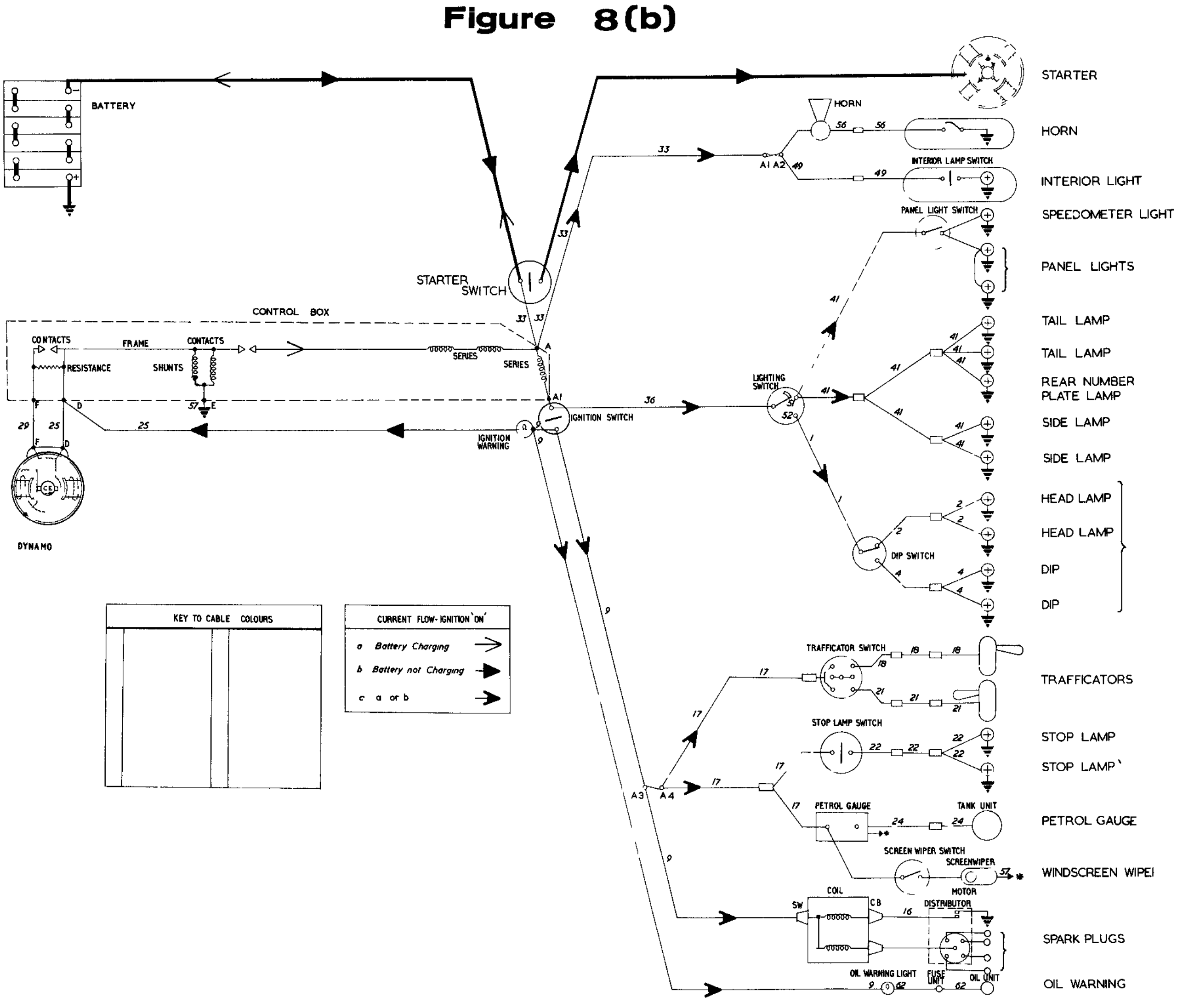
Figure 7b ORANGE PUTTER POWER SUPPLY CHAIN

Figure 8(a)



2416

Figure 8(b)



CAR ELECTRICAL SYSTEM

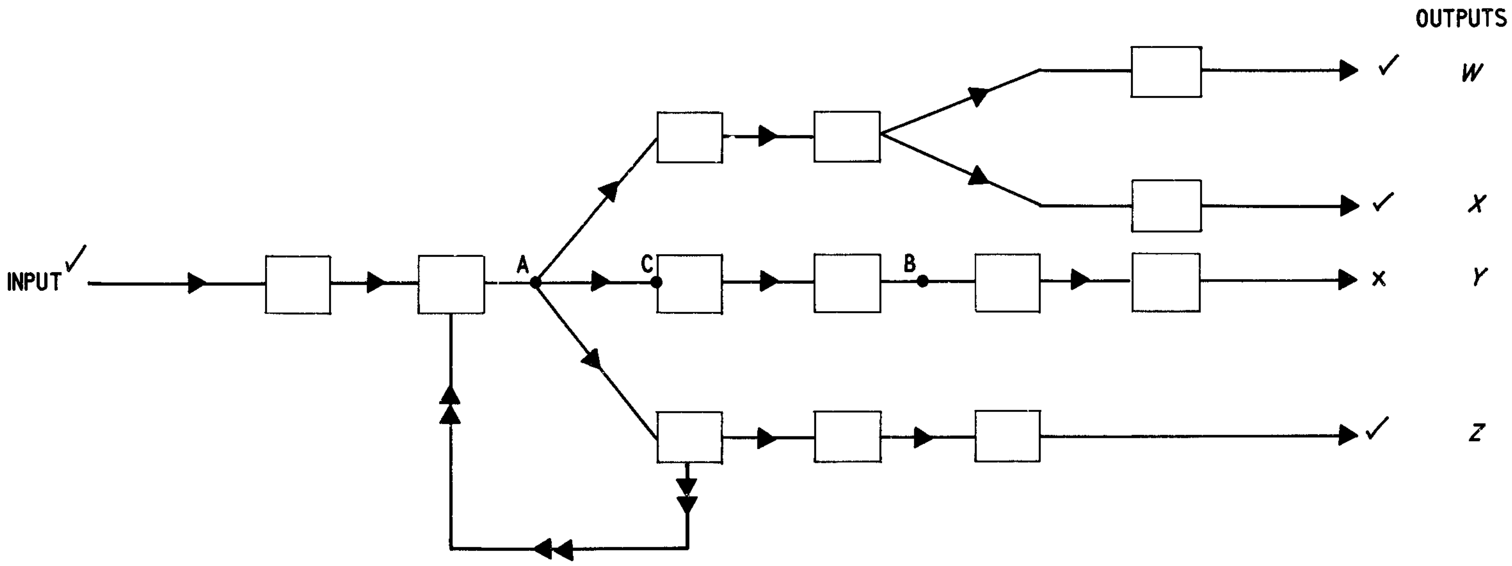


Figure 9 Theoretical Chain Diagram

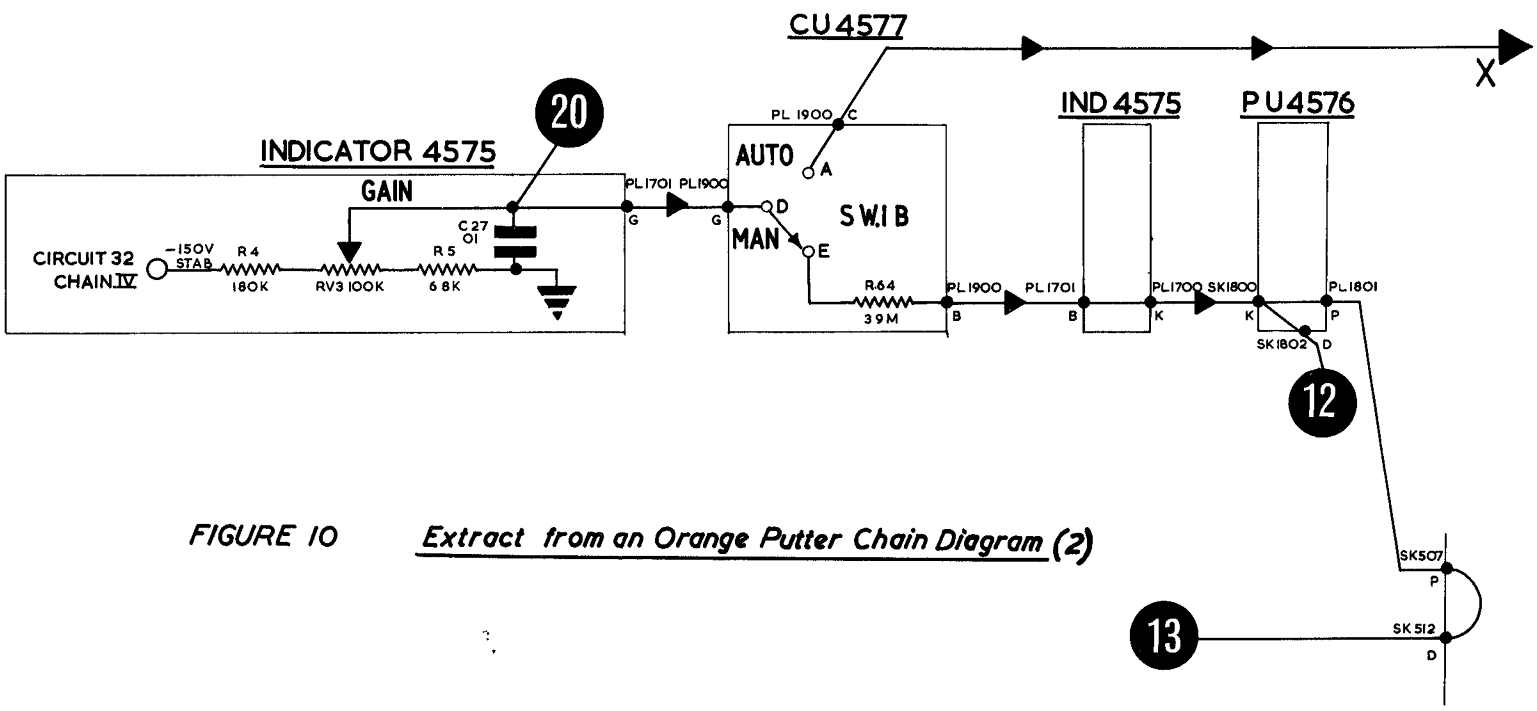
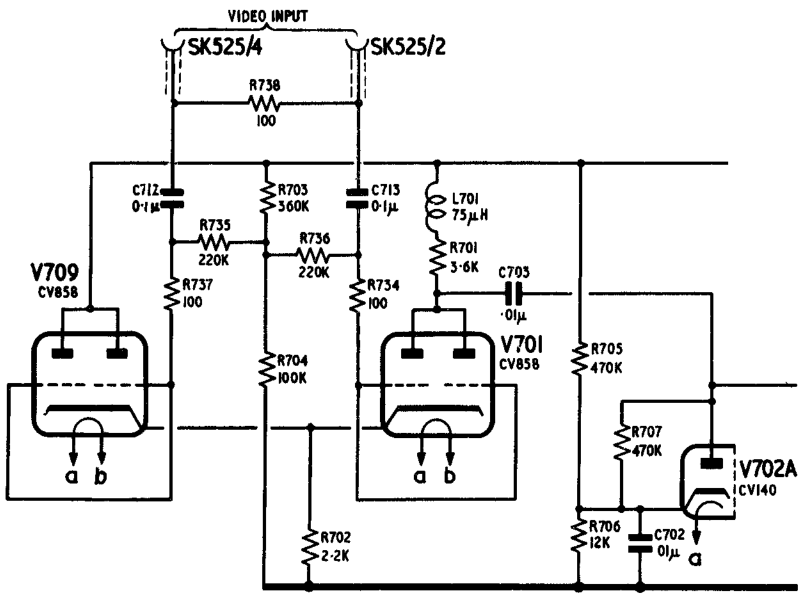


FIGURE 10 Extract from an Orange Putter Chain Diagram (2)



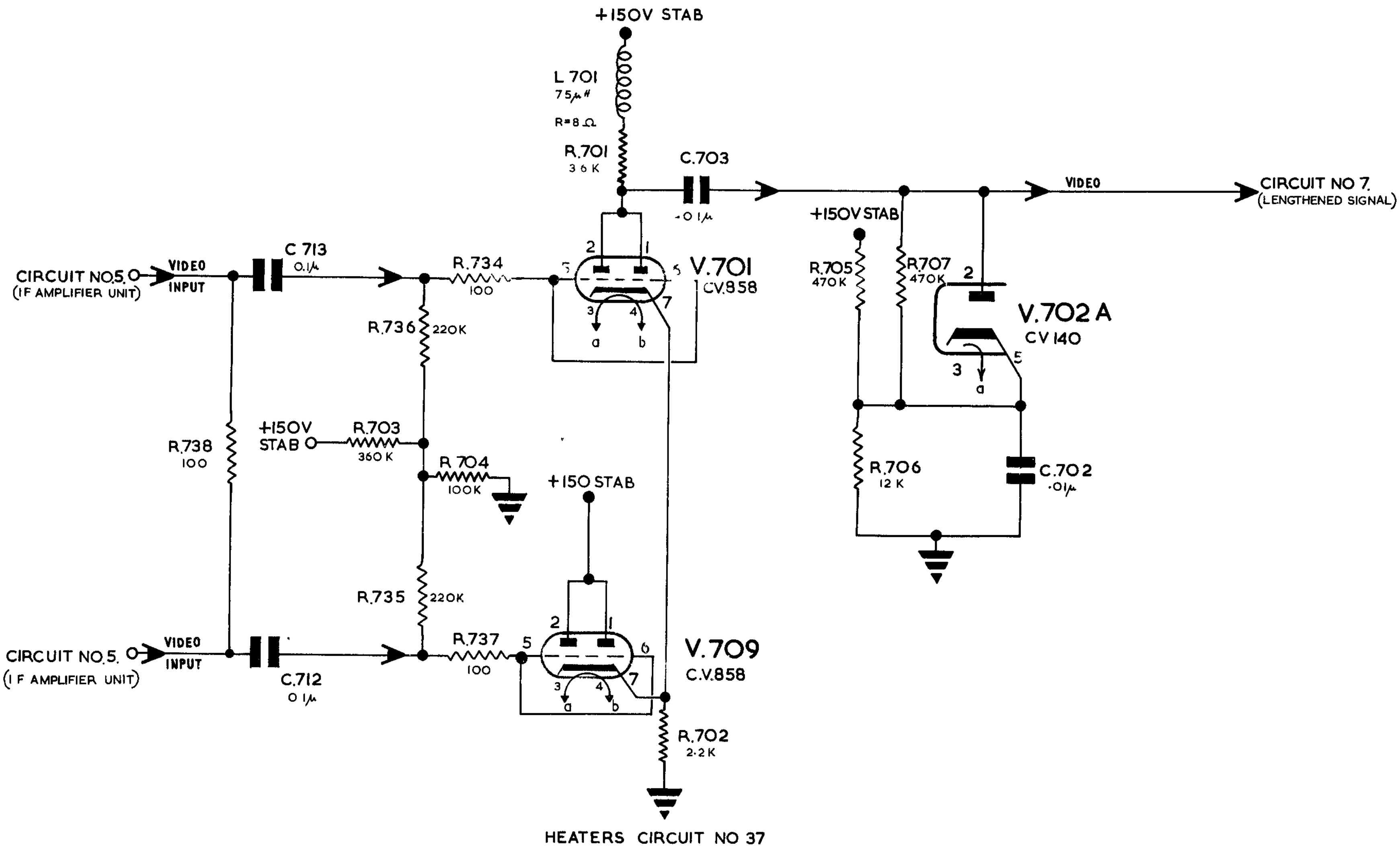
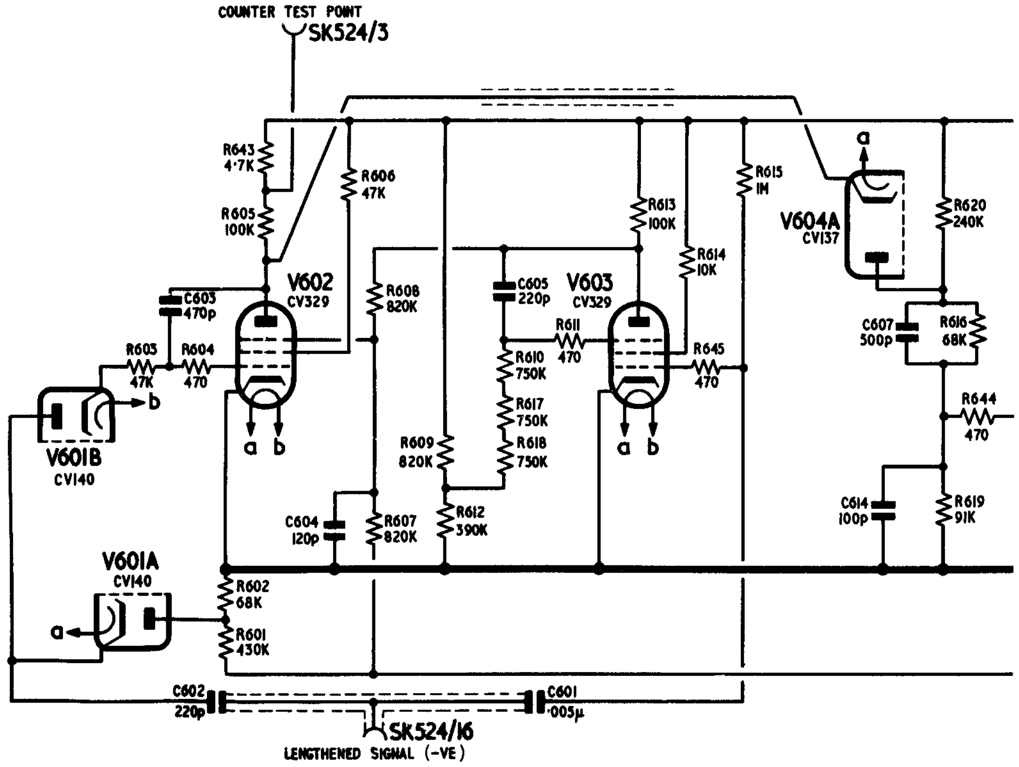
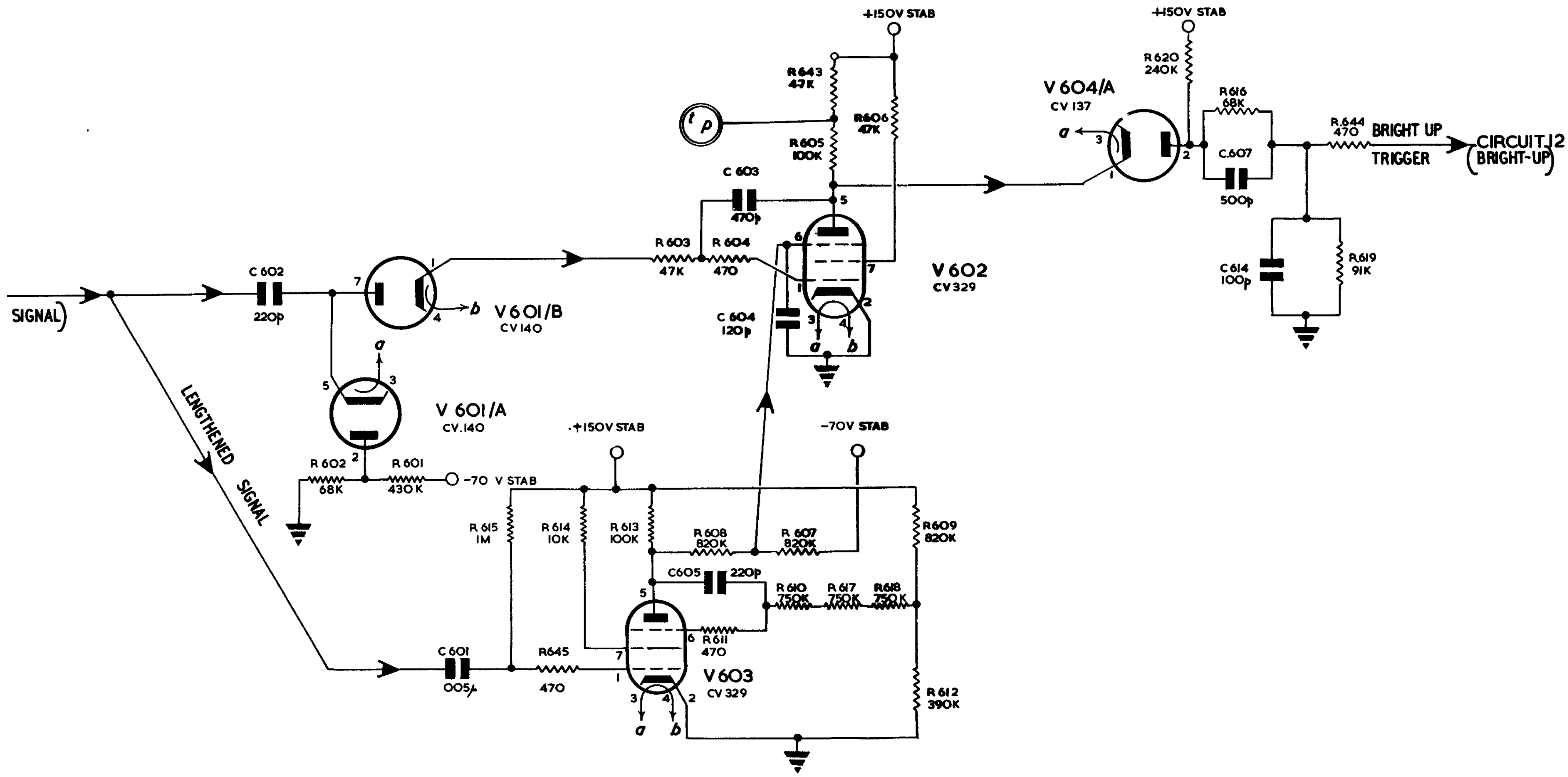


Figure 11. Orange Putter Video Amplifier.





HEATERS CIRCUIT NO 37

FIGURE 12. Orange Putter Counter.

Fig. 12

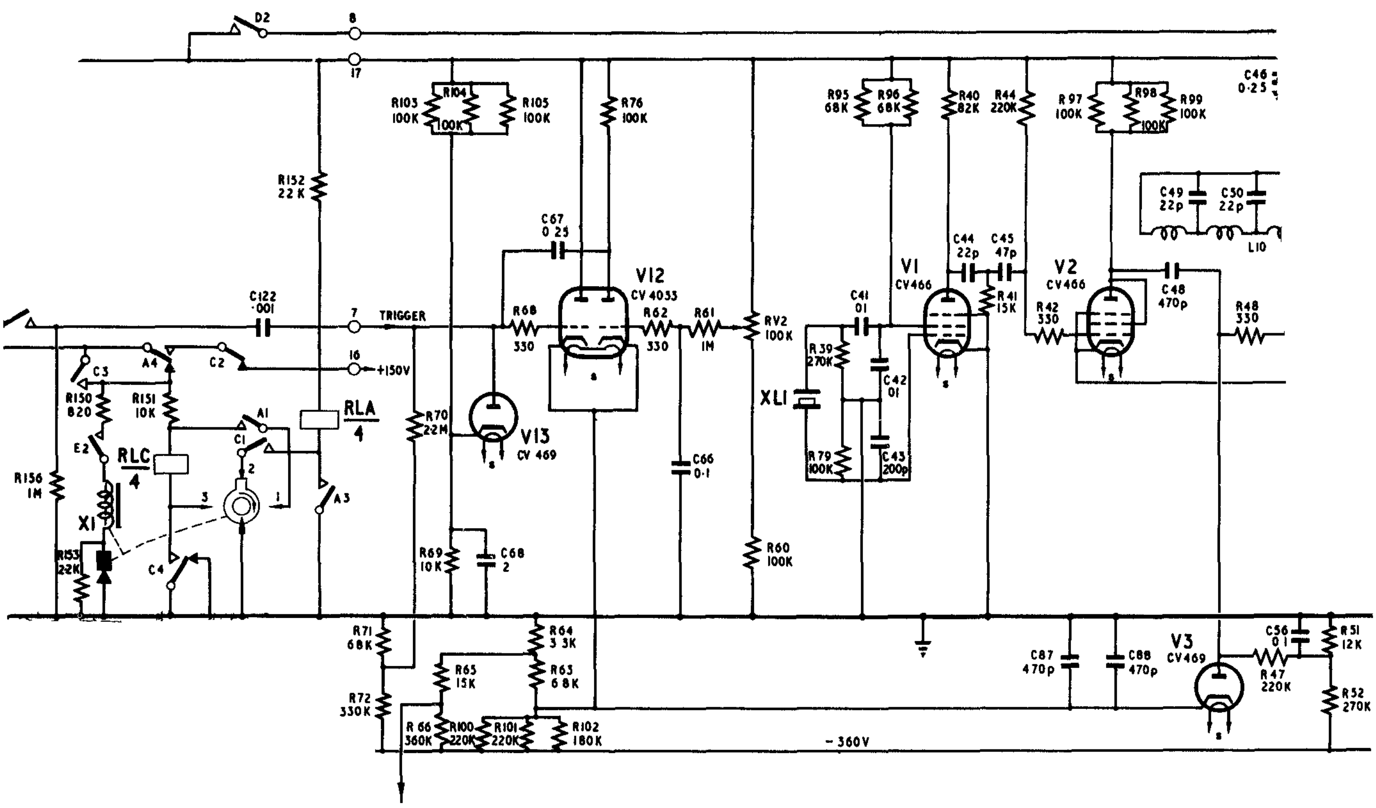


Figure 13. Long Gate Flip-Flop ORIGINAL

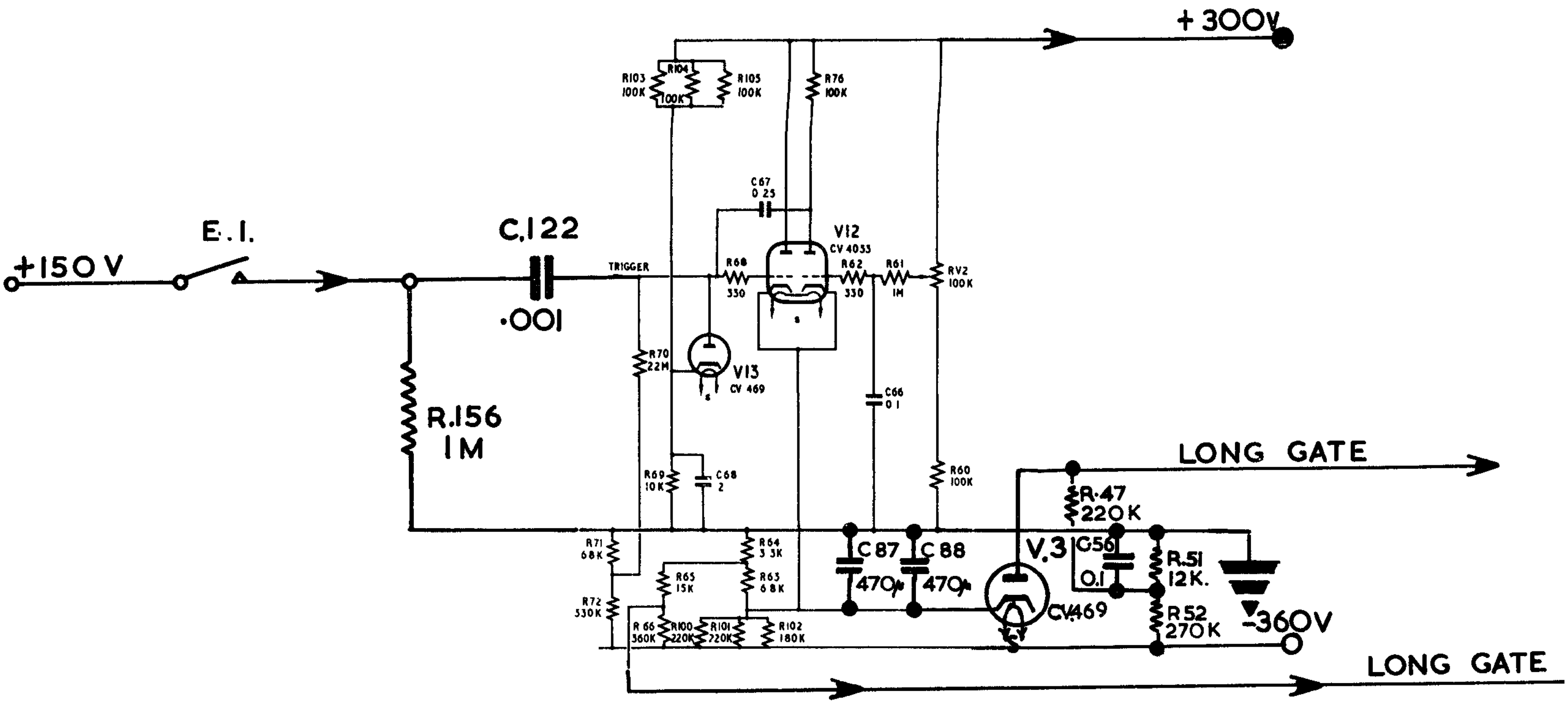


Figure 14 Long Gate Flip-Flop STAGE I.

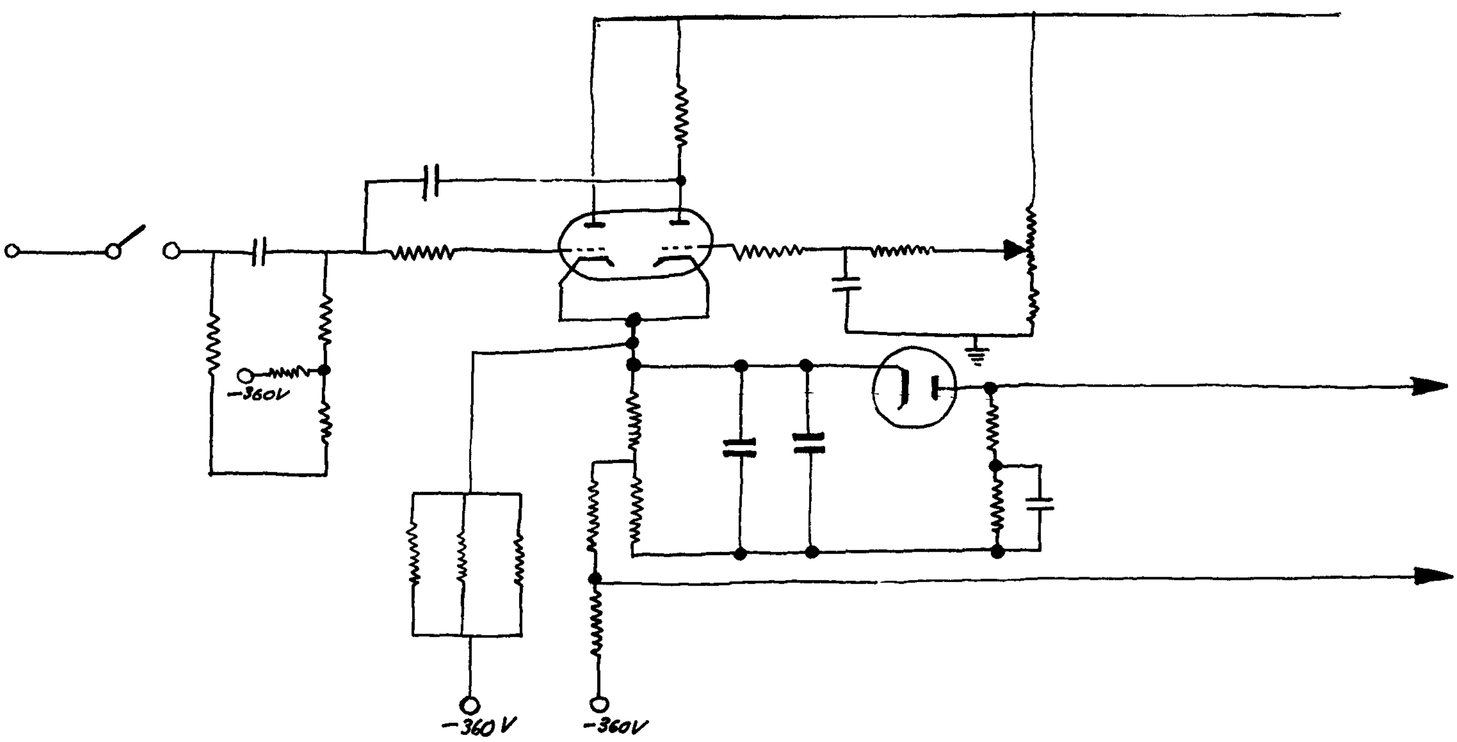


Figure 15. Long Gate Flip-Flop STAGE 2.

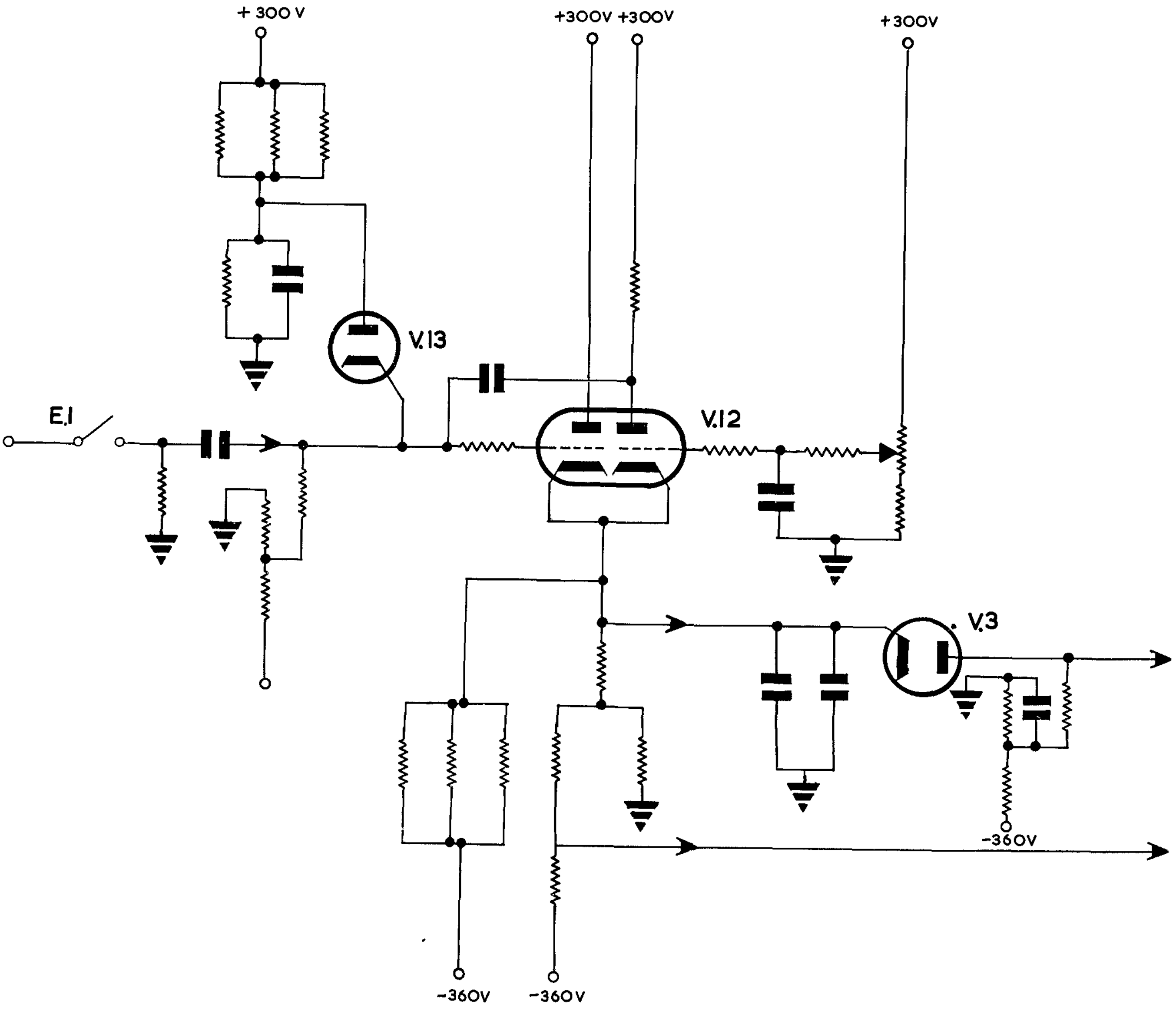


FIGURE 16 LONG GATE FLIP-FLOP STAGE 3.

Green Satin, List of Chain and Circuit Diagrams

GREEN SATIN

List of Chains

CHAIN I - Transmitter Chain
II - Received Signal Chain
III - Azimuth Chain
IV - Power Supply Chain
V - 26v a.c. and d.c. Chain. IND 101 and Tu 100

List of Circuit Diagrams

1. Long Gate Flip - Flop.
2. Crystal Oscillator.
3. Short Gate Flip - Flop.
4. Cathode Follower.
5. Modulator.
6. Magnetron, Klystron and Waveguide System.
7. First Intermediate Frequency Amplifier.
8. A.F.C. Unit.
9. Second Intermediate Frequency Amplifier, and Detector.
10. Audio Amplifier.
11. Pre-Amplifier.
12. Mixer Number 1.
13. Low Pass Filter and Audio Frequency Amplifier Number 1.
14. Mixer Number 2.
15. Low Pass Filter and Audio Frequency Amplifier Number 2.
16. Integrator Rectifiers.
17. Integrator Long Tailed Pair.
18. Integrator Magnetic Amplifier.
19. Integrator Motor and Gearbox.
20. Integrator Feed Back.
21. Phonic Wheel Velodyne.
22. Phonic Wheel Minor Magnetic Amplifier.
23. Phonic Wheel Major Magnetic Amplifier.
24. Phonic Wheel Gearbox.
25. Azimuth Rectifiers.
26. Azimuth Long Tailed Pair.
27. Azimuth Magnetic Amplifier.
28. Azimuth Motor and Gearbox.
29. Azimuth Feedback Loop.
30. Warning Circuit.
31. Signal to Noise.
32. Approximate Speed Indicator.
33. Indicator Automatic Gain Control.
34. Three Phase Special. +8Kv. and - 1Kv. Supplies.
35. +300v. and +150v. Supplies.
36. -360v., -500 v., - 660 v., and - 1.1 Kv. Supplies.
37. Heater Supplies TR 3710.
38. + 150 v. and ± 3 v. Supplies.
39. - 225 v. and - 75 v. Supplies.
40. Heaters TU 100.
41. + 150 v. Supply.
42. Heaters IND. 101.
43. Aerial Unit 501.

ORANGE PUTTER FUNCTIONAL CHECK

Purpose

(i) To show whether or not a fault exists on Orange Putter.
(ii) To indicate in which circuit or chain the fault lies.
(iii) To speed location of faults by listing functions that have already been checked.

How to Use the Functional Check

Col. 1. show what action is required in each step.
Col. 2. shows what is the expected result of each step.
Col. 3. indicates the faulty circuit or chain if the expected result is not obtained. It also shows what common sense checks should be made before investigation of the fault.
Col. 4. shows which circuits have been checked by each step.

(i) Keep to the order of steps shown in Col.1. Otherwise the remarks in cols. 2, 3, and 4 do not apply.
(ii) Do not continue with the functional check once a fault symptom has been discovered. The remarks in cols. 2, 3, and 4 are only correct if the expected result was obtained in all the previous steps.
(iii) When the expected result is not obtained, check only those circuits or chains shown in col.3.
(iv) When the expected result is not obtained, do not start fault finding until you have confirmed that a fault does exist. Make commonsense checks, i.e. cables, switch positions (see col.3) in order to ensure that the fault is not due to wrong setting up of the bench. Where the fault symptom occurs at a test point in the middle or beginning of a chain, check that the output of the chain is also faulty.

Scope of Functional Check

The check covers the functioning of all circuits on Orange Putter, but it does not check that all parameters are within the required specification or that the equipment is working at maximum efficiency.

1. Setting Up

Cables: Connect cables as shown in Diagram 1.

Test Gear: Meter Unit 4035 to SK 104 in Radar Head.
Monitor 102 in circuit between Radar Head and Waveform Generator - see Diagram 1.

Do not start the functional check until cable connections have been checked.

Switches: 28V and 115V bench supplies OFF.
Scanner OFF.
Warning Note OFF.
Suppression OUT.
M.U. 4035: Position 2.
Monitor: OFF.
Auto/Manual: MANUAL.

These switches are put in the OFF position at the start of the check, so that if a fuse blows when a switch is turned ON the area of search is limited to that controlled by the switch.

G scope Control Unit 611 :

L.S. rate control - do not adjust unless required to in step 13.

Min. range - fully anticlockwise.

Wings range - fully anticlockwise.

Max. range - fully clockwise

When adjusting preset controls take care to adjust the control screw and not the locking screw.

B Scope Control Unit 4577 :

Gain control - fully anticlockwise. (B. scope head).

Timebase Amplitude anticlockwise. (not fully).

Step No.	Col. 1 Action	Col. 2 Expected result if no fault	Col. 3 Possible location of fault if expected result not obtained	Col. 4 If the correct result is obtained these circuits have been checked
2a	<u>Power ON</u> Switch on the 115V 1,600 C/S bench supply (Righthand Switch)	A.C. Meter shows 115V.1600 C/S whine should be heard.	Chain IV, meter or source of supply.	Indicates absence of a short to earth or between wires, on any part of circuit which is connected directly to input.
2b	Turn Auto/Man. switch to Auto and look at A.C. Meter.	A.C. Meter still shows 115V.	If meter now shows zero volts, a fuse has blown because there is a short on 115V input to WFG from Auto/Man switch to TR.501 and TR.502. Confirm fault by checking whether valves light up. Check that supply is on at bench by switching on monitor.	Absence of short to earth on 115V input from Auto/Man switch to WFG.
	<u>G Scope Display</u> Centralise Scanner. (Scanner should be pointing outwards and inclined at about 25° above horizontal. Cables and plugs should be at top of Radar Head).			
3a	Observe G scope. (If spot is not visible attempt to bring it on to the screen by adjustment of Az and El shift and amplitude controls, and brightness control).	A spot with or without wings on G scope. (The spot need not be in centre of screen, depending on setting of Az and EL controls). Absence or presence of wings or $\frac{1}{2}$ a wing at this stage is NOT a fault.	Chain II, Chain III, Chain IV. Check that Auto/Man switch is on Auto and that cables at SK 507 and SK506 are connected.	a).Input to TR502, -1.5KV output, and part of outputs supplying heaters in CRT.13, 26. b). Input to TR.501 and part of outputs supplying heaters to G scope (Cct 13). c) Inputs to TR103 and TR101, and their outputs which are peculiar to +220 & +180V supplies in Chain IV.
3b	Adjust brightness control in C.U. 611.	Brightness of spot varies with adjustment of control.	Brightness circuitry.(Cct.13)	Brightness control in C.U. 611 and cct. 13.

Step No.	Col.1	Col.2	Col.3	Col.4
4	Adjust G scope FOCUS control, For normal running of equipment use Brightness and Focus controls to get a small well defined spot (or wings) about the size of a pin head.	The definition of the spot should vary with adjustment of Focus control.	Bright-up and C.R.T. (Cct.13)	Cct. 13 excluding B.U. facility.
	B Scope Display			
5a.	Observe B scope.	A vertical line on B scope. (It may be necessary to adjust B scope Az. and Range Shift controls if line does not appear. The length of the line is not important at this stage. Ignore internal reflections within C.R.T.).	Chains II, III, IV, Check that pre-pulse cable is connected from Radar Head to B scope via W.F.G. Check B scope connections at SK. 507.	a) Input to TR 1 (Ind.4575) and its output to B scope C.R.T. heater. b) -1.5 KV supply (Cct.33). c) Input to TR 1(P.U.4576) and its outputs from ccts. 31 and 32 to 33 d) Inputs to TR 2 (P.U.4576) and heater supplies to ccts. 31 32 & 33. e) Cct. 1 & pre-pulse output to B scope. f) +220V supply from cct. 30 to cct.1. g) Heaters to ccts. 30 and 1.
5b.	Adjust B scope brilliance control on Ind.4575.	Brilliance of line varies with adjustment of control.	Brilliance control circuitry. (cct.22)	Brilliance control circuitry.
6.	Adjust B scope FOCUS control on Ind.4575	The definition of the line should vary with adjustment of Focus control.	C.R.T. Unit (B.S.) (Cct. 22) If brilliance is up too high it will be impossible to focus line.	Cct. 22 excluding inputs from Ccts. 23, 24 and 21.