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THE COLLEGE OF AFRONAUTICS

DEPARTMENT OF ELECTRICAL AND CONTROL ENGINEERING

THE DESIGN OF THE MAN/MACHINE INTERFACE FOR A TRANSISTOR TESTER

Supervised by: D. Whitfield.

CoA Ergonomics Laboratory,
Control Engineering Group
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The C.o.A Group and	Section Contributed.
Mr. O. Farrelly	2
Mr. J. Mearns	3
Mr. W. Corner	4
Mr. N. Fitzgerald	5
Mr. J.J. Narraway	6

All the C.o.A group are in the Electrical and Control Engineering Dept.

1. INTRODUCTION

This project is a practical exercise in system design undertaken by the previously named group of Electrical and Control Engineering students. The object of the project is the practical embodiment of ergonomic and systems design concepts incorporated within a lecture series in the subject. The whole project took place over the Spring Term and part of the Summer Term of the 1964/65 Academic Year.

The material in this report was arrived at by considerable discussion amongst the whole group, although for convenience in the following text, the sections were each compiled by an individual member. This method of compilation has led to a small amount of overlapping between sections.

The project itself is concerned with the design of the interface between a machine for carrying out tests on transistors and the operator of such a machine. In essence it amounts to the design of the controls and display panel. The commercial version of this instrument, made by the American firm Tektronix, was not examined until late in the project and consequently much of the design arrived at by the C.O.A. (College of Aeronautics) group is original.

The C.O.A. group wish to acknowledge the help and guidance given by Mr. D. Whitfield of the Ergonomics Laboratory, C.O.A., during this project.

2. OBJECTIVES AND ERGONOMIC DESIGN TECHNIQUE

2.1. Summary

The object was to design a machine for testing transistors and diodes using systems design techniques. Due to lack of time the actual circuitry to do such tests was not investigated but was assumed to be technically feasible. The final design was evaluated from the point of view of:

(1) available facilities

(2) system design

(3) man/machine interface

by comparison with the commercial Tektronix instrument. The use of the word transistor for the introductory part of the report covers both transistors and semi-conductor diodes.

2.2. System inputs and outputs

All the input and output requirements of the machine were listed, categorised under general headings, as in Fig. 1.

2.3. Functional Diagram

The input variables (to test a transistor) were separated and put down in roughly sequential order giving a functional diagram. For purposes of clarity only the interrelations showing the main flow of information through the device has been shown. The block marked "How" has been expanded in Fig. 3. The block marked "protection" is to protect the machine from damage due either to insertion of a faulty transistor or to mis-handling of the machine.

The functional block diagram to a large extent dictated the allocation of function between man and machine.

2.4. Operation sequence diagram

This was constructed from the functional flow diagram, and is shown in Fig. 4. This yielded:

1. The minimum number of operations to get the required output, and characteristics.

2. The sequence of operations to get the required output. These enable a provisional interface to be designed.

2.5. Safety of Transistors

Before the actual interface could be designed the potential user-population had to be considered, with a view to arranging protection of transistors from destruction by faulty settings of the machine. (The safety of the machine has been considered in an earlier section.) In view of the fact that the large majority of users would be trained laboratory personnel, who would know the limitations of the device under test (from manufacturers data or experience), the number of operations could be cut to a minimum and their sequence left to the discretion of the user.

In view of the foregoing it was considered that the proper operation of an adequate set of input controls constituted a form of device protection.

2.6 Interface Design

As a visual display is always required, a C.R.O. tube was adopted. For detailed viewing a 6" tube was thought adequate. For correct viewing the C.R.O. tube was placed at eye-level, and for correct insertion of transistors (fore-arms resting on the table) the input sockets for transistors were placed at the base of the instrument. A double input socket with a three-way switch was incorporated for comparison of transistors; the switch centre position electrically isolated both transistor sockets.

The arrangement of the controls was guided by using:

1. The sequential operation approach.

2. The functional grouping and display/control relationship approach.

The C.R.O. controls were arranged by the functional grouping approach. The remainder of the controls however demanded a compromise between the two methods adopted above. After discussion the interface shown in Fig. 5 was adopted.

3. FINAL LAYOUT OF INTERFACE

Fig. 6 shows the complete layout of the interface. Fig. 7 shows in detail the types of labelling and marking to be used for the different controls. The instrument is provided with two bases so that two similar devices may be inserted and the characteristics of one compared with thoses of the other. The Selector Switch between the bases also has an OFF central position so that setting new positions of the controls cannot damage the device.

The Mode switch has three positions, these being Diode, N.P.N. and P.N.P. and is set according to the type of device being tested. Next the Configuration Switch is used when testing transistors. It is used to select the relative position of the transistor in the circuit, that is, it selects whether the transistor has a grounded base, emitter or collector. The Characteristic Switch also has three positions and is used to select the type of characteristic required. The three characteristics available are the Input, Output and Transfer characteristics, which when combined with the configuration switch gives a total of nine characteristics. The other controls are all concerned with the display, and they have been conceptualised in terms of a typical graph showing the relationship between three variables. Thus, we have the independent variable (on the horizontal axis), the dependent variable (on the vertical axis) and the reference parameter (discrete steps of a third variable, for each of which is shown the relationship between the other two variables).

For the "independent variable", we have two Sweep controls: Range and Level. The range control selects the range of the independent variable, and has both voltage and current scales, either being used according to the type of characteristic selected. The level control is a variable resistor by means of which the independent variable can be adjusted between 0 and 100% of the range selected.

There are two "reference parameter" controls. One selects the number of characteristics (i.e. number of values of the reference parameter) to be displayed, and the other selects the interval between each of the values of the reference parameter.

For the "dependent variable", we have the Vertical Scaling control, which is used to adjust the size of the display. It is used to select the range of the dependent variable with respect to the display required so that by adjusting it the optimum size of the display can be achieved.

The three Circuit Switches vary the loads in the three legs of the circuit and their effect on the characteristics can be observed on the display. When the collector switch is used the collector voltage is displayed and not the input voltage.

The size of cathode ray tube decided upon was six inches. The other controls are concerned with obtaining the optimum display. A protection is provided for the device by means of a cut-out and warning light with a reset button which will connect the device back into the circuit after the fault has been rectified.

4. OPERATIONAL PROCEDURES FOR BOTH INSTRUMENTS

4.1 Initial Adjustments of Instrument:-

Tektronix Instrument:-

1) Power switch on - observe indicator lamp.

2) Adjustments of trace (a) Intensity, (b) Focus, (c) Astigmatism } observe trace

3) Adjustment of vertical deflection (a) Zero check (D.C. Balance), (b) Position } observe trace

4) Adjustment of horizontal deflection (a) Zero check, (b) Position } observe trace

Proposed CoA Instrument:-

1) Mains switch on - observe indicator lamp.

2) Adjustment of trace (a) Brilliance, (b) Focus, (c) Astigmatism } observe trace

3) Adjustment of Vertical deflection (Y-Shift)

4) Adjustment of Horizontal deflection (X-Shift) } observe trace

4.2 Selection of Item for Testing

1) Note reference numbers and/or type (mode).

2) Refer to manufacturers data - where available.

3) Decide on nature of test, or tests, required.

4.3 Testing Procedure

N.B. Simplified basic test of transistor in common emitter configuration only.

Tektronix Instrument:-

1) Isolate terminals (Transistor Selector in centre position).

2) Collector sweep polarity.

3) Collector peak volts range.

4) Collector volts to zero.

5) Adjust series resistor (collector).

6) Base step generator to single family/repetitive.

7) Set steps per family.

8) Choose step polarity.

9) Choose step interval.

10) Adjust series resistor (base).

11) Set vertical deflection sensitivity.

12) Set horizontal deflection sensitivity.

13) Insert item to be tested.

14) Terminals switch to A or B.

15) Vary peak volts (increase slowly) - observe trace.

Proposed CoA Instrument:-

1) Isolate terminals switch to off.

2) Select mode of operation (P.N.P./N.P.N./DIODE).

3) Select configuration (common emitter/base/collector)

4) Select characteristic required.

5) Collector sweep level to zero.

6) Collector sweep range to maximum desired.

7) Choose base step interval.

8) Choose number of steps/family.

9) Set vertical deflection sensitivity.

10) Adjust series resistor - collector.

11) " " " - base.

12) " " " - emitter

13) Insert item to be tested.

14) Terminals switch to A or B.

15) Vary sweep level - observe trace.

The basic test may be extended for both instruments as below:

a) The number of steps displayed may be varied whilst observing.

b) The step interval may be varied whilst observing.

c) The value of the series resistors can be varied whilst observing.

(N.B. load line is displayed on Tektronix - this facility was also envisaged in regard to the CoA instrument).

d) Two transistors may be compared by use of both sets of terminals and manual operation of the selector switch - N.B. matching.

e) Variation of the vertical sensitivity of the display whilst observing.

f) Variation of the horizontal sensitivity whilst observing.

g) Check leakage (open circuit or short circuit input).

N.B. Via spring loaded switch on Tekronix

Via adjustment of terminal connections only with CoA.

h) Adjustment of step zero (starting level). Available via potentiometer control on Tektronix. Would probably have been necessary to provide similar control on CoA.

For testing in other configurations it is desirable to run through a complete test procedure to avoid applying wrong polarities or amplitudes in the case of the Tektronix instrument or wrong amplitudes in the case of the CoA instrument. This also applies when wishing to observe different characteristics.

4.4 Different Configurations are Available by:-

a) Tektronix Instrument:-

1) Operation of a switch for lower power devices in common emitter or common base.

2) Changing terminal wiring for all other conditions.

b) CoA Instrument:-

Operation of a switch.

4.5 Different Characteristics may be Obtained by:-

a) Tektronix Instrument

Adjusting step generator and vertical and horizontal display sensitivities.

b) CoA Instrument

Operation of switch and vertical scaling sensitivity.

4.6 Different Modes of Operation are Available by:-

a) Tektronix Instrument

Operation of sweep polarity switch and operation of step clarity switch.

b) CoA Instrument

Operation of mode switch.

Internal resistance of devices and diode testing can be achieved in both instruments by appropriate connections at the terminals with appropriate operation of the other controls (i.e. only collector sweep would normally be used for this purpose).

Figures 8 and 9 indicate, by means of the "string diagram" technique, the spatial sequence of operation of controls for the Tekronix instrument and the CoA instrument respectigely, when both are used for the "common emitter" test described previously in section 4c.

5. COMPARISON OF FACILITIES AVAILABLE ON BOTH INSTRUMENTS

5.1 The Tektronix Curve Tracer, although flexible, is designed around the common emitter configuration of transistor operation and this is reflected in the labelling employed on the interface. To test a transistor in any other configuration it is necessary to refer to the instruction manual and exercise care in setting up the instrument before making any measurements. The input terminals are also designed for 'common emitter' operation, a special plug/socket arrangement being necessary for 'common base' operation.

5.2 On the other hand the College of Aeronautics (CoA) Curve Tracer is designed from the consideration of the transistor as a four terminal network. By the simple setting up of three switches, any transistor (or diode) can have its input, transfer, or output characteristic displayed for any of the three circuit configurations. Further there is no difficulty about the input connection of the transistor. The instrument also has a protection system to prevent overloads which are indicated by a warning light. A reset button is provided.

5.3 The Table in Fig. 10 gives a comparison of the facilities available on each instrument. In effect it is only a tabulation of their facilities since a number of controls on the Tektronix have no direct equivalent on the CoA instrument and vice versa.

5.4 It is obvious that the Tektronix Instrument has had much development work done on it. It has a number of very useful facilities from the operational point of view. They include both zero check and zero adjustment facilities on both the horizontal and vertical deflection controls, calibration checks etc. Some other facilities which appear to be missing for the CoA instrument, such as polarity selectors are included in the mode characteristic and configuration switches.

6. APPRAISAL OF THE OPERATION OF THE CoA INSTRUMENT

This is with particular reference to the use of the CoA instrument to obtain the common emitter characteristics of a device, which probably is the most used test.

6.1 Control Grouping

The controls are grouped in such a way that one handed operation of the system seems feasible. This is similar to the practice adopted for the Tektronix instrument although here the groups are different since in particular that instrument is more specific than the CoA one, and they are spaced more widely than on the CoA leading to larger hand movements. If viewing the trace through a hood, as is sometimes done, then the feel of the CoA instrument might be better on this score. This however is a point which can be decided only by construction of a model of the CoA instrument for trials to take place. The CoA instrument would benefit by a more complete panel section labelling system as does the Tektronix.

6.2 Movements

The number of movements on the CoA instrument required for the specific test as above, is 15, the same as the Tektronix. The total distance moved on the CoA instrument for the same general panel size would almost certainly be less.

Using the figs. 8 and 9,

$$\frac{\text{Dist. Moved on CoA}}{\text{Dist. Moved in Tektronix}} = \frac{48''}{64''} = \frac{3}{4}$$

In some applications this might be significant. However, the complexity of the path of movements seems to be similar for both instruments. Generally, bearing in mind experience in operating the Tektronix, the CoA instrument would be at least as easy to handle.

6.3 Display

The CoA instrument has a good display of output data. There are no obstructions to viewing and both hands can be used to operate display controls (brilliance, etc.) and inputdata controls without difficulty as is experienced if this is attempted on the Tektronix.

In general this layout represents a good basis for the panel of a general h parameter display instrument for three terminal networks and particularly for transistors.

6.4 Range of performance

The CoA Instrument possesses all the basic controls required for h parameter measurement and display, and these, where applicable, correspond to the Tektronix controls.

Various ancillary adjustments appear on the Tektronix panel which do not appear on the CoA unit. These are in the main, adjustments to the electronic circuitry within the instrument case and would appear where required on a fully engineered CoA instrument.

With the CoA instrument, certain circuit design procedures can be carried out on the instrument, and with a little adaptation in the form of extra switch functions to display additional data, then there would result a very flexible circuit design tool, as well as device tester.

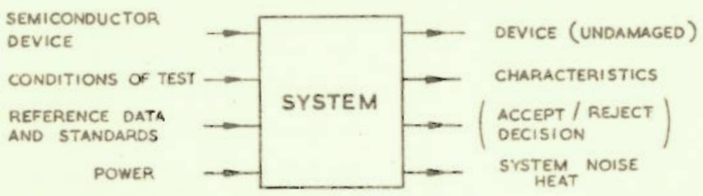

FIG. 1 SYSTEM DESIGN

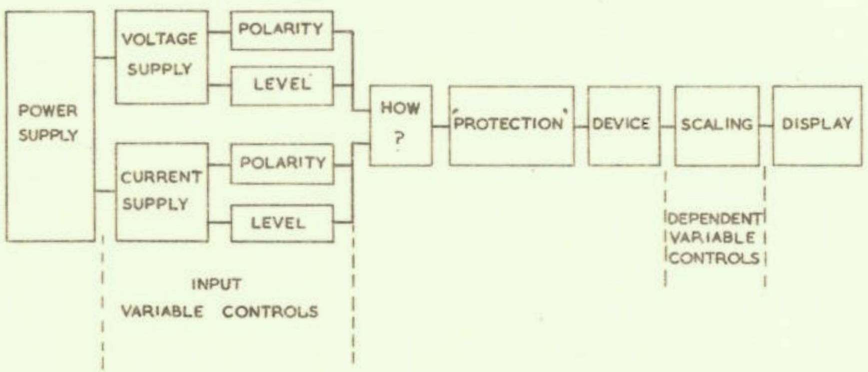

FIG. 2 FUNCTIONAL DIAGRAM

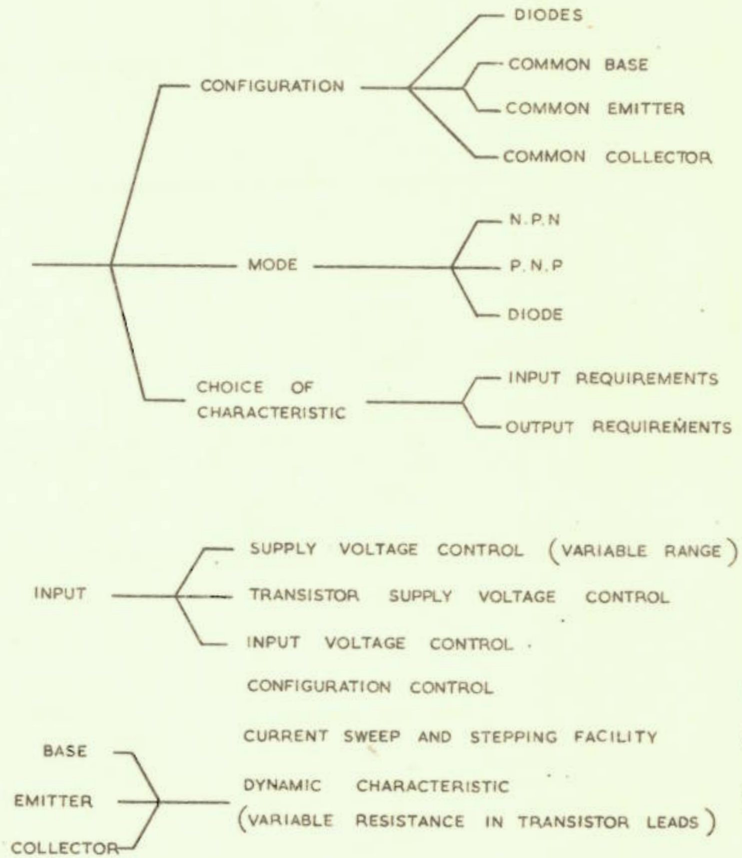

FIG. 3 'HOW'

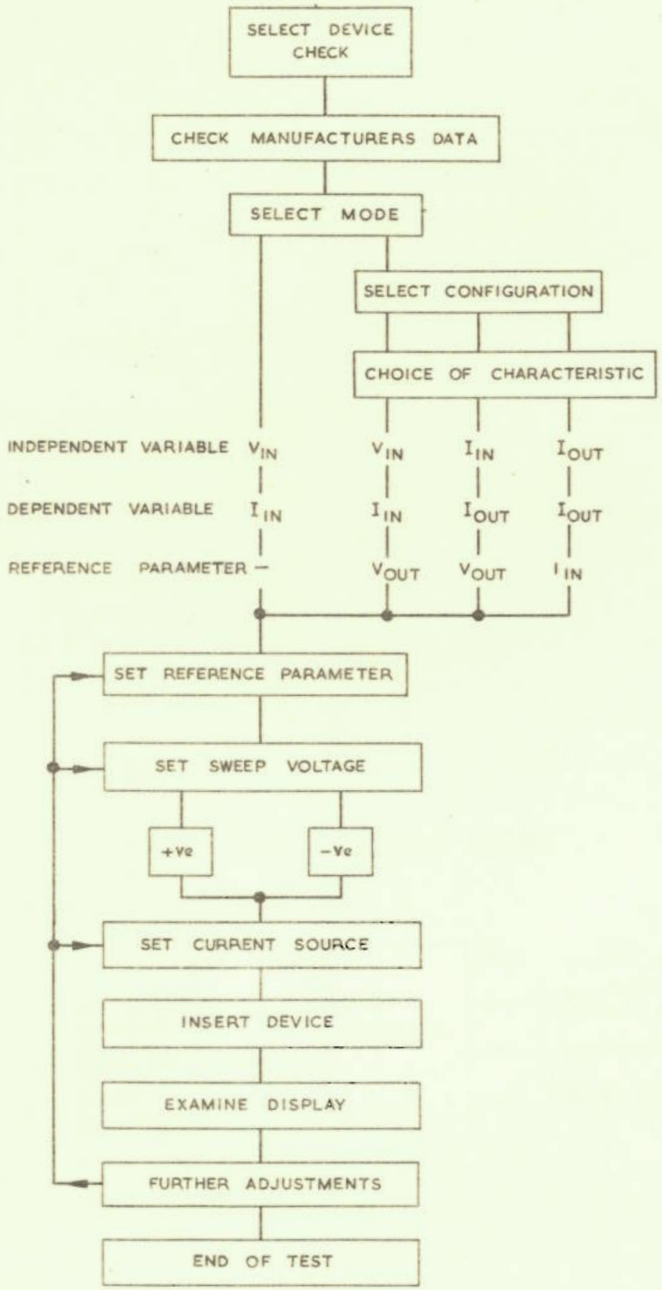

FIG. 4 OPERATION SEQUENCE DIAGRAM

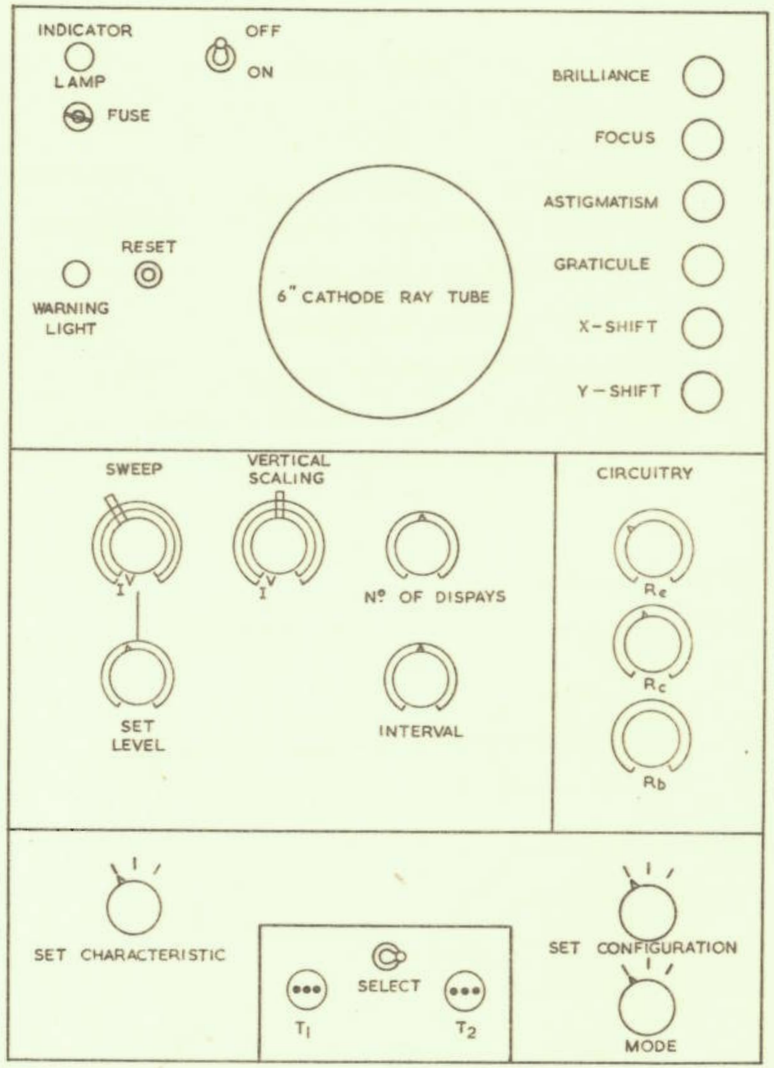

FIG. 5 PROVISIONAL INTERFACE

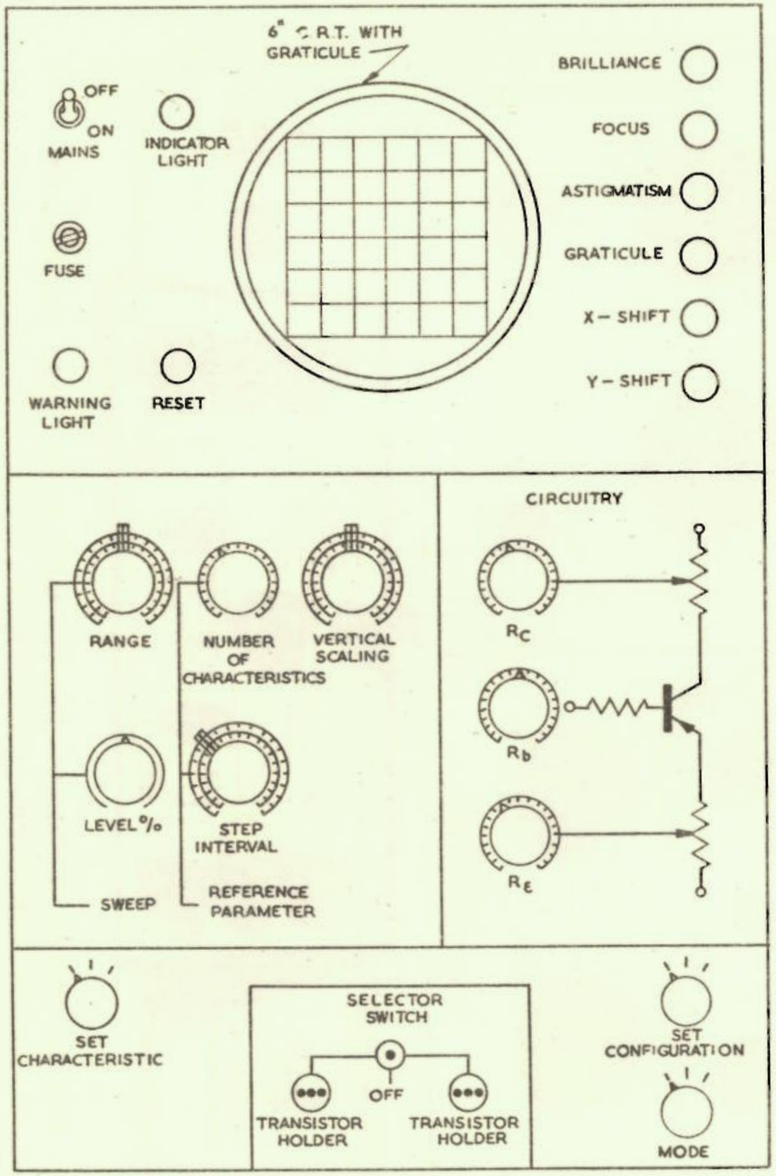

FIG. 6. FINAL LAYOUT

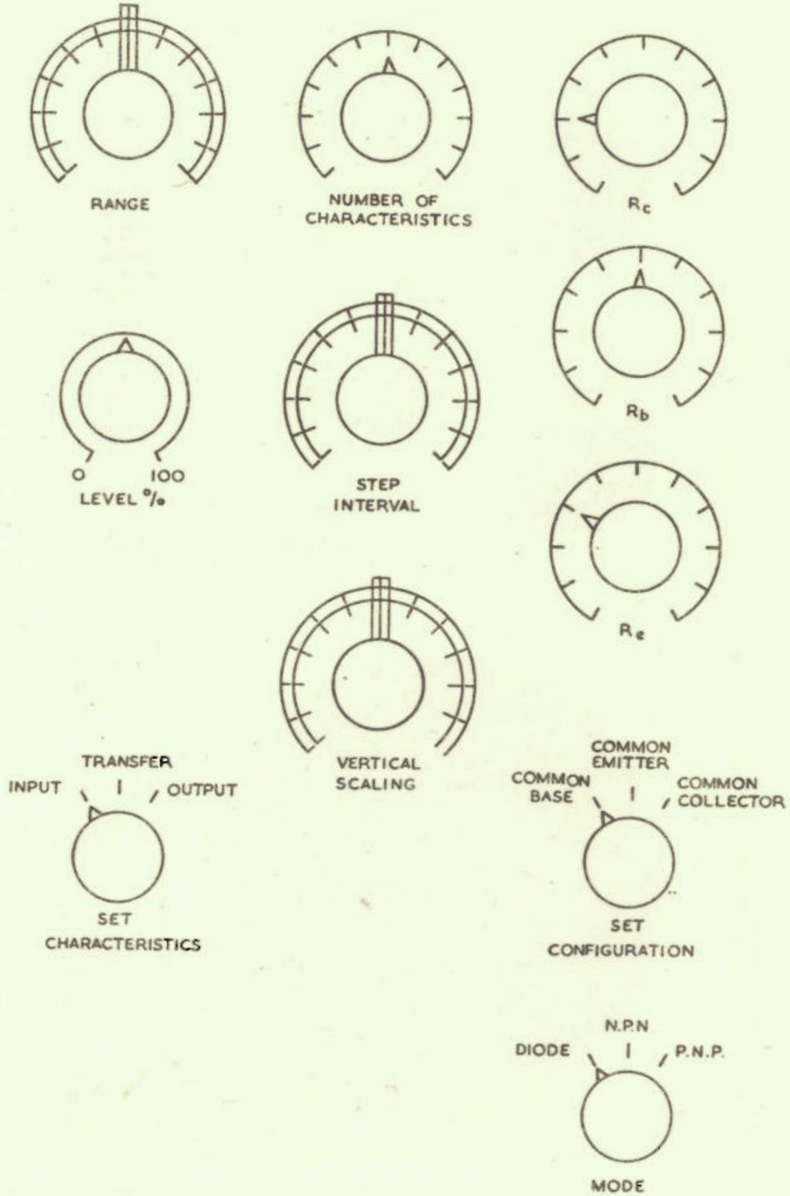

FIG. 7 CONTROLS

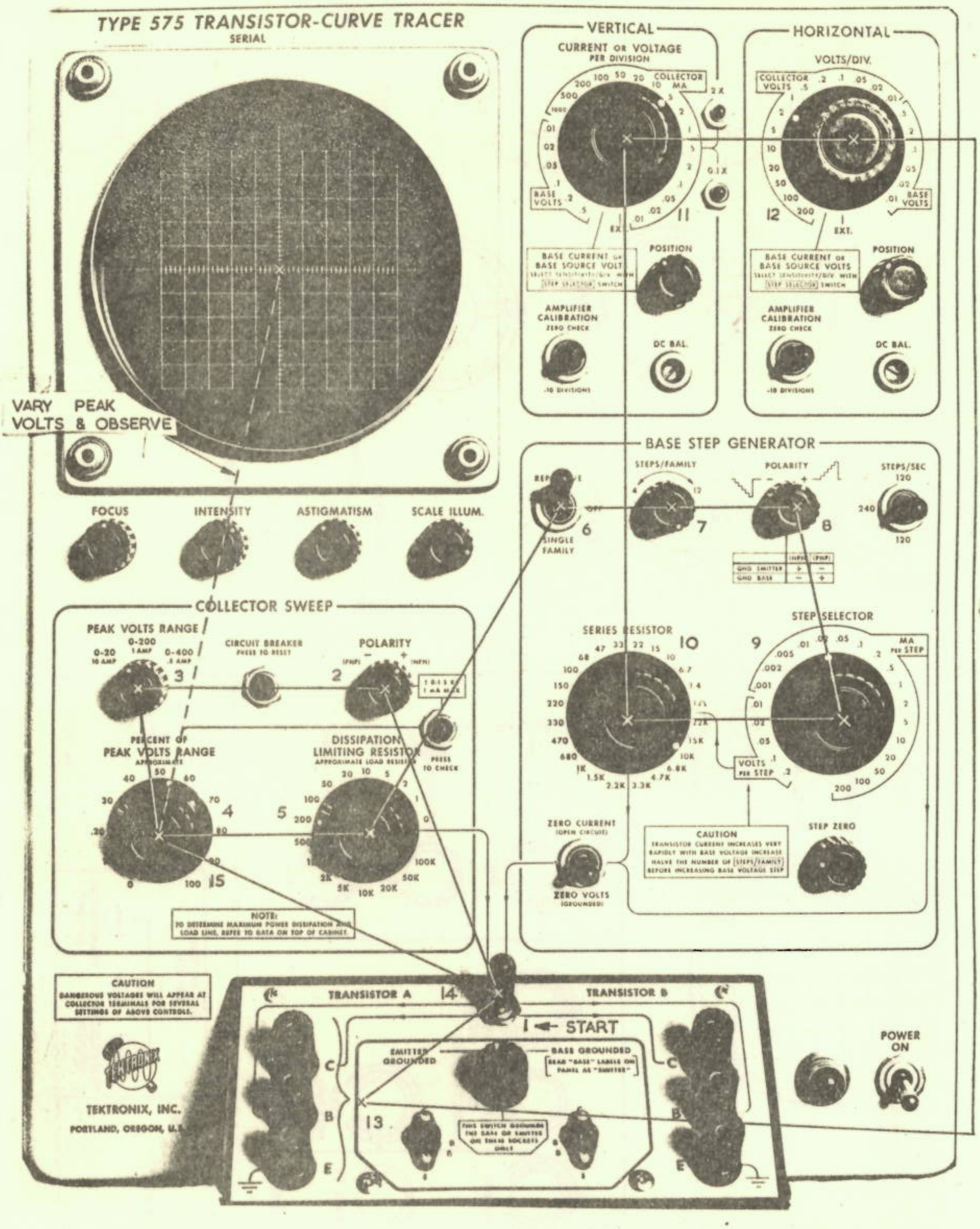

FIG. 8 STRING DIAGRAM OF TYPICAL BASIC TEST PROCEDURE ON TEKTRONIX INSTRUMENT

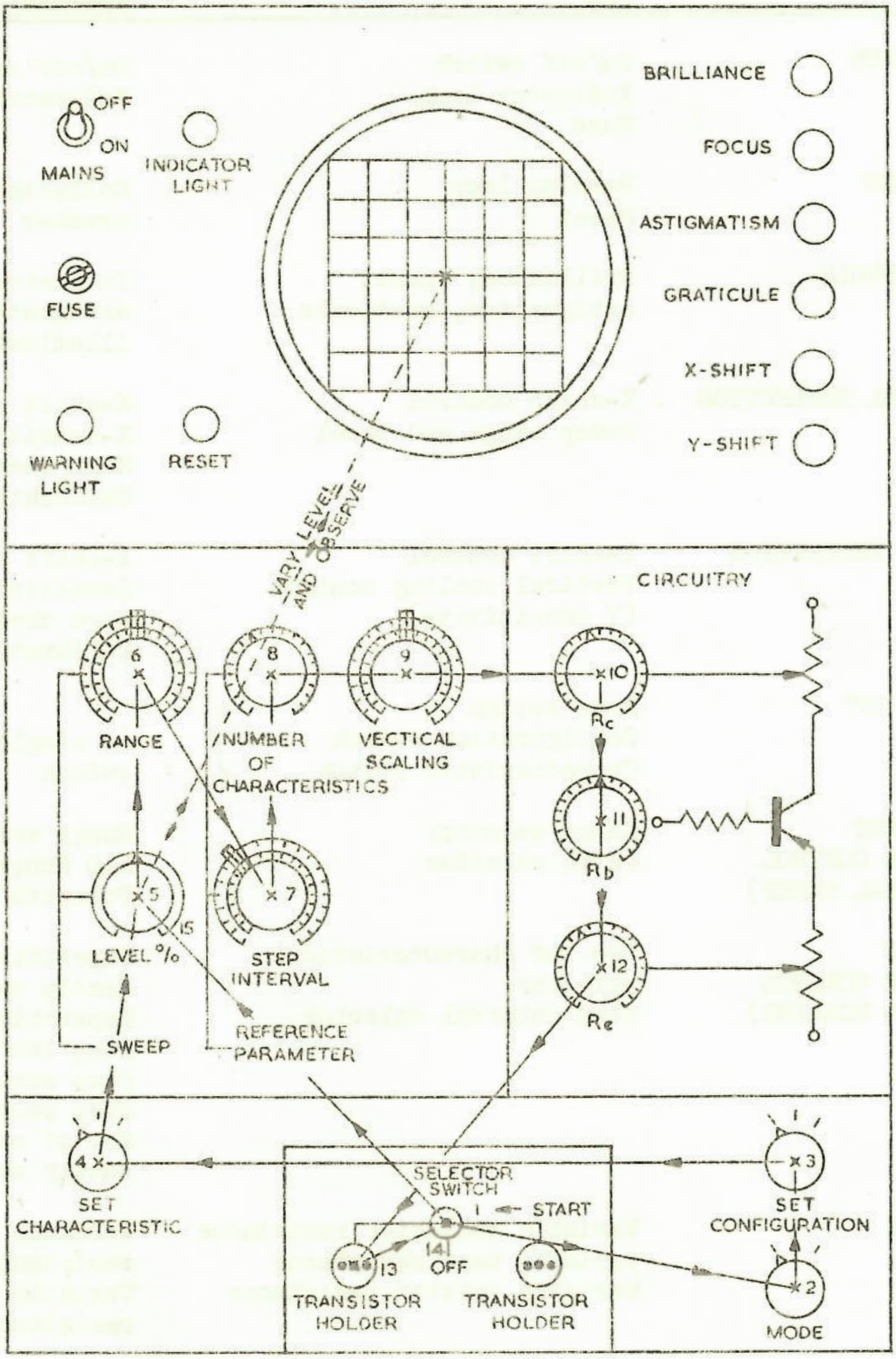

FIG. 9 STRING DIAGRAM OF TYPICAL BASIC TEST PROCEDURE ON C OF A INSTRUMENT.

FIG. 10 - COMPARISON OF FACILITIES

FUNCTION	CoA	TEKTRONIX
POWER INPUT	On/off switch Indicator lamp Fuse	On/off switch Indicator lamp
PROTECTION	Warning lamp Reset	Collector sweep circuit breaker
TUBE CONTROLS	Brilliance, focus, astigmatism, graticule	Intensity, focus, astigmatism, scale illumination
HORIZONTAL DEFLECTION CONTROLS	X-shift control Sweep range and level	X-shift control X-sensitivity control Zero check button Calibration check button
VERTICAL DEFLECTION CONTROLS	Y-shift control Vertical scaling control (Y sensitivity)	Y-shift control Sensitivity control Zero check Calibration check
'SETTING UP' CONTROLS	Mode switch Configuration switch Characteristic switch }	no single equivalent switch
INDEPENDENT PARAMETER CONTROL (HORIZONTAL SWEEP)	Range selector Level selector	Range selector X10 Range switch Polarity selector
REFERENCE PARAMETER CONTROL (VERTICAL SCALING)	'No. of characteristics' selector Step interval selector	Repetitive/single family switch Repetition rate switch Step interval selector Step zero adjustment Step polarity selector No. of steps per family selector
CIRCUITRY	Variable collector resistance Variable base resistance Variable emitter resistance	Variable collector resistance Variable base resistance
MISCELLANEOUS	Terminal selector switch	Terminal selector switch Leakage current monitor.