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Report No. 2383/3384/1
Date - 3 APR 1963

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ELECTRICAL DEPARTMENT

ADMIRALTY ENGINEERING LABORATORY

WEST DRAYTON, MIDDLESEX

HARMONIC RESPONSE TESTER [U]

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ADMIRALTY ENGINEERING LABORATORY

WEST DRAYTON, MIDDLESEX.

HARMONIC RESPONSE TESTER

Investigators:-

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E.C. Tapper, B.Sc.
D.J. Parsons

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SUMMARY

The development of a portable harmonic response tester for a.c. servo systems is described up to the construction of the laboratory prototype model. The equipment is largely transistorised and provision is made for incorporating a d.c. adaptor, the design of which is discussed, at a later date.

HARMONIC RESPONSE TESTER

1. INTRODUCTION

A harmonic response tester for servo systems was developed at the Laboratory in 1954 and 4 models were constructed. The evaluation and use of these instruments for obtaining Nyquist diagrams for weapon-control servo systems showed a number of limitations in their electrical characteristics. In addition the two units comprising the tester were too heavy for easy portability.

A start was made in 1959 to design a transistorised version incorporating a number of refinements. Many difficulties were experienced during the early development, largely because of the limited range of transistors available; as silicon types became available, difficulties due to d.c. drifts were gradually eliminated.

Considerable effort was expended in designing an amplifier suitable for a dual tester (for a.c. and d.c. servo systems) but the required closed-loop gain was 1000 and the versions developed proved insufficiently stable. Eventually it was decided to concentrate on a model suitable for a.c. only, which would cater for the majority of Service systems. The agreed specification for this version is shown in the Appendix, and a general view of the equipment is shown in Fig.1.

2. BASIC SYSTEM (Fig. 2)

The tester was designed for analysis of servo systems employing a 400 c/s carrier and provision is also made for operation on 1100 c/s supplies (to be tested).

The signal generator section has a maximum output of 10V (peak) into a load of minimum impedance 1 kΩ, and its modulation frequency can be set (in 2 ranges) from 0.15 to 50 c/s. An additional facility gives a frequency sweep from the set frequency to zero. Provision is made for variable reset.

The amplitude and phase measuring section has an input impedance of more than 1 MΩ with both input and output terminals isolated from earth and each other. A.C. (i.e. modulated carrier) signals only can be accepted. Amplitude is read directly while phase change is obtained by a nulling method.

A stabilised power supply unit provides d.c. rail voltages of +20, 0 and -20V.

3. SIGNAL GENERATOR (Fig. 3)

The signal generator incorporates a gearbox in which two Type 11 CX4b synchros geared 10:1 are driven by a velodyne system. The speed of the velodyne system thus determines the modulation frequency of the 400 c/s signal. Size 18 motor and tachogenerators are used and the gearbox is screened to reduce interference generated by their commutators.

A simple d.c. amplifier provides the drive for the motor, with negative feedback from the tachogenerator. The frequency is set by a logarithmic potentiometer (RV4) which gives good setting control at the low speeds.

/The

The maximum frequency of 5 c/s on low range (50 c/s on high range) is preset by feedback adjustment (RV2); the minimum frequency, about 0.15 c/s, is preset by a bias adjustment (RV3).

A frequency sweep which has a choice of two decay times can be selected by SW7.

A switched output transformer provides an output which can be set over the range of 0 to 10V (peak) with an error of less than 1 mV (peak).

4. RESET AMPLIFIER (Fig. 4)

A resetting device can be inserted in series with the generator output to give a variable value of feedback in ranges 0-5%, 5-10%, 10-20%, 20-50% and 50-100%. It is essentially a transformer-coupled amplifier with a push-pull output employing overall feedback for gain control.

5. AMPLITUDE MEASUREMENT (Fig. 5)

The response signals from the servo under analysis are connected to the reset and amplitude amplifiers by a screened unit containing a high-impedance isolating transformer and a double triode with buffer-stage transistors.

The range switch SW8 allows direct reading of signals at ranges 10 mV, 100 mV, 1V and 10V.

The amplitude amplifier is a.c. coupled with considerable local feedback on each stage, the overall voltage gain being adjusted to 1000. Its output is connected through separate demodulating circuits to the amplitude metering circuit and the phase measuring circuit.

The output from the demodulator in the metering circuit is virtually the peak-to-peak value of the modulation which is referred to the base of the first emitter-follower. As the meter is calibrated to measure 20V peak-to-peak and the amplifier overall gain is 1000, the most sensitive f.s.d. is when 20 mV peak-to-peak is applied. Because of diode voltage drops in the demodulator, the smallest signal measurable is 2 mV peak-to-peak, and the scale (marked 0-10V) has the lower portion obliterated.

6. PHASE MEASUREMENT (Fig. 6)

A Type 11 CT4b synchro is included in the phase measuring circuit and the phase of its output may be set by hand to any desired value with respect to the response signal. It is connected to the Type 11 CX4b synchros in the signal generator.

The output of the Type 11 CT4B synchro is fed via a reference transformer to a demodulator summing circuit in which it is added to the error-signal output of the amplitude amplifier. The sum of the voltage is fed to the grids of a pair of electrometer triodes controlling an emitter-pair coupled through a centre-zero microammeter.

When the phase change is nulled correctly the meter needle swings equally about the centre, the frequency and amplitude of swing being dependent on the modulation frequency.

Provision is made for quiescent balance of the electrometer triodes.

/7.

7. POWER SUPPLY UNIT (Fig. 7)

The power supply circuit is conventional and consists of two linked identical full-wave rectifier circuits fed from a transformer. The 25V supply for the signal generator velodyne is also derived via rectifiers from the same transformer.

The unit also includes switches used for setting up the amplifiers and making pre-operational checks. The mains input switch is contained on a separate chassis (Fig. 3).

8. FIRST LABORATORY PROTOTYPE

The first prototype uses IMHOF modular chassis mounted in two 19 x 7 in. frames bolted together, making the overall size 20 x 16 x 11 in. Most of the transistor circuitry is mounted on VEROBOARD and the units plug into MICROCON sockets.

A further report will describe the use of this unit on various servo systems.

9. SECOND LABORATORY PROTOTYPE

A number of improvements will be made in the design and construction of the second model and may be applied retrospectively to the first.

These include:

(a) Use of smaller meters which will reduce the width of the amplitude and phase measuring units and the signal generator unit to 4 in.

(b) Redesign of the gearbox so that the fast-driven synchro is declutched when the signal generator is being used on the low-frequency range. The use of an in-line motor-tachogenerator is also being considered.

(c) Redesign of the phase indicator to replace the present gearing, dial and geneva wheel mechanism by a counter.

10. D.C. ADAPTOR

Provision is made for the inclusion of a d.c. adaptor in Model 1. It is envisaged that this would take the form of a low-gain d.c. amplifier (chopper-stabilised) followed by a modulator. It would also include a demodulator for the signal generator.

There are considerable difficulties in developing this circuitry and it may be decided that the limited use with d.c. does not justify the over-complication of the tester.

HARMONIC RESPONSE TESTER

APPENDIX

Specification for Harmonic Response Tester - 115V, 400 c/s Servo Systems

(200V, 1100 c/s systems with minor modifications)

(a)	Signal levels	1 mV to 10V peak of carrier
(b)	Minimum tester input impedance	> 1 M Ω
(c)	Modulation frequency range	0.15 to 5 c/s 5 to 50 c/s
(d)	Sweep frequency exponential decay time constants	30 seconds 140 seconds
(e)	Minimum load impedance	1 kΩ
(f)	Maximum load voltage	10V peak
(g)	Accuracy of phase measurement	2°
(h)	Response amplitude	1 mV to 10V peak
(i)	Resetting control steps	0:5:10:20:50:100%
(j)	Input	Isolated (earth and output)
(k)	Output	Isolated (earth and input)
(l)	Power supply	As for servo under test

HARMONIC RESPONSE TESTER

COMPONENTS LIST

Circuit Ref.	Description	Patt. No.	Value	Tol. ±%	Rating
Resistors			Ohms		Watts
R1	Composition G-1	021-5281	2.2K	5	¼
R2	"	021-6145	220K	"	"
R3	"	021-6965	1M	"	"
R4	"	021-6129	120K	"	"
R5	"	021-6051	27K	"	"
R6, R7, R8	"	021-6001	10K	"	"
R9	"	021-5241	1K	"	"
R10	"	021-5021	15	"	"
R11	"	021-6129	120K	"	"
R12	"	021-6962	10M	"	½
R13	"	021-0796	18K	1	⅛
R14	"	021-0724	1.8K	"	"
R15	"	021-0652	180	"	"
R16	"		20	"	"
R17	"	021-6101	68K	5	¼
R18	"	021-5341	6.8K	"	"
R19	"	021-6101	68K	"	"
R20	"	021-5271	1.8K	"	"
R21	"	021-6101	68K	"	"
R22	"	021-5341	6.8K	"	"
R23	"	021-5211	560	"	"
R24	"	021-6925	330K	"	"
R25	"	021-5341	6.8K	"	"
R26	Wire Wound		330		6
R27	Composition G-1	021-5271	1.8K	"	¼
R28, 29			100	2	1½
R30, 31, 32	Composition G-1	021-5620	820	"	¼
R33, 34	"	021-5640	1K	"	"
R35, 36	"	021-6211	10K	"	"
R37, 38	"	021-5800	4.7K	"	"
R39, 40 41	"	021-6450	100K	"	"
R42	"	021-5720	2.2K	"	"
R43	"	021-6350	39K	"	"
R44	"	021-6291	22K	"	"
R45, 46	"	021-6271	18K	"	"
R47	"	021-6370	47K	"	"
R48	"	021-5640	1K	"	"
R49	"	021-0778	10K	1	⅛
R50, 51	"	021-0727	2K	"	"
R52, 53, 54	"	021-0706	1K	"	"
R55	"	021-0790	15K	"	"
R56	"	021-0715	1.5K	"	"
R57	"	021-0706	1K	"	"
R58	"	021-0709	1.1K	"	"
R59	"	021-0778	10K	"	"
R60, 61	"	021-0727	2K	"	"
R62	"	021-0706	1K	"	"
R63, 64, 65	"	021-6211	10K	2	¼
R66	"	021-5341	6.8K	"	"
R67	"	021-6251	15K	"	"
R68	"	021-5640	1K	"	"

HARMONIC RESPONSE TESTER

COMPONENTS LIST

Circuit Ref.	Description	Patt. No.	Value	Tol. ±%	Rating
Resistors (contd.)			Ohms		Watts
R69, 70	Composition G-1	021-6962	10M	5	$\frac{1}{2}$
R71, 72	"	021-6962	10M	"	"
R73, 74	"	021-6121	100K	"	$\frac{1}{4}$
R75, 76	"	021-5251	1.2K	"	"
R77, 78	"	021-6041	22K	"	"
R79, 80	"	021-5101	68	"	"
R81, 82		021-5701	1.8K	2	$\frac{1}{2}$
R83, 84	Wire Wound	A.P.52443	3		2
R85, 86	Composition G-1	021-5640	1K	2	$\frac{1}{4}$
R87, 88	"	021-5581	560	2	$\frac{1}{2}$
R89, 90	Wire Wound	024-5001	1	10	$\frac{3}{4}$
R91	Composition G-1	021-6211	10K	2	$\frac{1}{4}$
R92, 93	"	021-0849	100K	2	$\frac{1}{8}$
R94, 95	"	021-0849	100K	2	"
Potentiometers					
RV 1	RVC 15A	011-9467	50K	20	$\frac{1}{4}$
RV 2	Trimpotr.	972-7194	20K	10	$\frac{1}{2}$
RV 3	"		10K	10	"
RV 4	Log-potr.		25K		
RV 5	Trimpotr.		5K	10	$\frac{1}{2}$
RV 6	"		1K	10	$\frac{1}{2}$
RV 7	"		5K	10	$\frac{1}{2}$
RV 8			5		
RV 9	Trimpotr.		100	10	$\frac{1}{2}$
RV 10	RVW2	011-9861	5K	10	$\frac{1}{2}$
RV 11	"	011-9857	250	"	"
RV 12	"	011-9853	10	"	"
RV 13	RVC 15A	011-9468	100K	20	$\frac{1}{4}$
RV 14	Trimpotr.		100	10	$\frac{1}{2}$
RV 15	"		100	"	"
RV 16	RVW2	011-9853	10	10	$\frac{1}{2}$
RV 17	RVW8	027-2142	10K	"	1
Capacitors			µF		Volts
C1, 2	Electrolytic (TA) (Pellet)	012-0138	140	20	30
C3, 4	Electrolytic (TA)	014-5334	10		150
C5, 6	"	"	10		"
C7, 8, 9,			1		"
C10, 11	Electrolytic (TA)	014-5297	25		50
C12			0.1		
C13	Electrolytic (TA)	012-0138	140	20	30
C14		Z115571	1	25	350

HARMONIC RESPONSE TESTER

COMPONENTS LIST

Circuit Ref.	Description	Patt. No.	Value	Tol. ±%	Rating
Capacitors (contd.)			µF		Volts
C15		012-0600	0.05		250
C16, 17		Z116311	1		150
C18, 19		"	1		"
C20, 21	Electrolytic (TA)	Z145328	15		100
C22, 23	"	"	15		"
C24	Electrolytic (TA) (Pellet)	012-0138	3 x 140	20	30
C25	"	"	3 x 140	"	"
C26, 27	"	"	140	"	"
C28	"	"	2 x 140	"	"
Diodes					
D1, 2		000-4073			
D3, 4		"			
D5, 6		000-4074			
Meter	Rectifier-Test	"			
D7, 8	ZR11	037-2024			
D9, 10	"	"			
D11, 12	"	"			
D13, 14	"	"			
D15, 16	IS113	037-2000			
D17, 18	"	"			
D19, 20 } D21, 22 }	ZR21	037-2013			
Meters					
Amplitude	B.P.L. 6714/1 5000 Ω/V				
Phase	B.P.L. 8271/2 2010Ω				
Frequency	B.P.L. 8271/1 1800 Ω				
Zener Diodes					Volts
Z1		037-2392			9.1
Z2, 3		037-2203			6.8
Z4, 5		037-2205			8.2
Z6, 7, 8		037-2392			8.2
Z9, 10, 11		"			"
Synchros etc.					
T/F 11CT4B					
TX 11CX4B					
Motor 5UD/6662					
T.G. 18 PM/R					

HARMONIC RESPONSE TESTER

COMPONENTS LIST

Circuit Ref.	Description	Patt. No.	Value	Tol. ±%	Rating
Transistors				Type	
T1, 2	2S005	037-2111		Si	NPN
T3, 4	"	"		"	"
T5	OC205	037-2529		"	PNP
T6	OC29	037-2158		Ge	"
T7, 8	2S005	037-2111		Si	NPN
T9, 10	"	"		"	"
T11, 12	"	"		"	"
T13, 14	"	"		"	"
T15, 16	"	"		"	"
T17, 18	"	"		"	"
T19	"	"		"	"
T20	OC29	037-2158		Ge	PNP
T21	2S005	037-2111		Si	NPN
T22, 23	2S018	037-2116		"	"
T24, 25	2S005	037-2111		"	"
T26, 27	OC23	037-2100		Ge	PNP
T28, 29	OC77	037-2007		"	"
Valves					
V1	12AU7	CV4003			
V2, 3	ME1401	CV2269			
Switches			Function		
SW 1	D/P ON-OFF		Main Supply I/P.		
SW 2	D/P 2 Posn.		Frequency C.O.S.		
SW 3	CS/2P/11/1B	Painton	TR1 Primary Tap C.O.S.		
SW 4, 5, 6	CS/1P/10/1B	"	O/P Volts Level		
SW 7	S/P 3 Posn.		Run-Sweep		
SW 8	S1450/4/A000/A	Ardente	Amplitude Range		
SW 9	3/P 3 Posn.		Cal. - Run - Dump		
SW 10	S1450/6/AAA0/A	Ardente	% Reset		
SW 11	S1450/6/BBBB/A	Ardente	Test 1		
SW 12	S1450/6/BB00/A	"	Test 2		
Transformers		Function			
TR1	RPC 573	Signal Output 90 r.m.s./0-10 Vp.			
TR2	RPC 588	High Impedance Isolating.			
TR3	RPC 593	Reset Amplifier Driver.			
TR4	RPC 589	" " Push Pull O/P.			
TR5	RPC 578	Reference Voltage.			
TR6	RPC 597	Stab. Power Supply 2(20.5V) 1(25V)			

FIG. I.

HARMONIC RESPONSE TESTER.

LABORATORY PROTOTYPE MODEL.

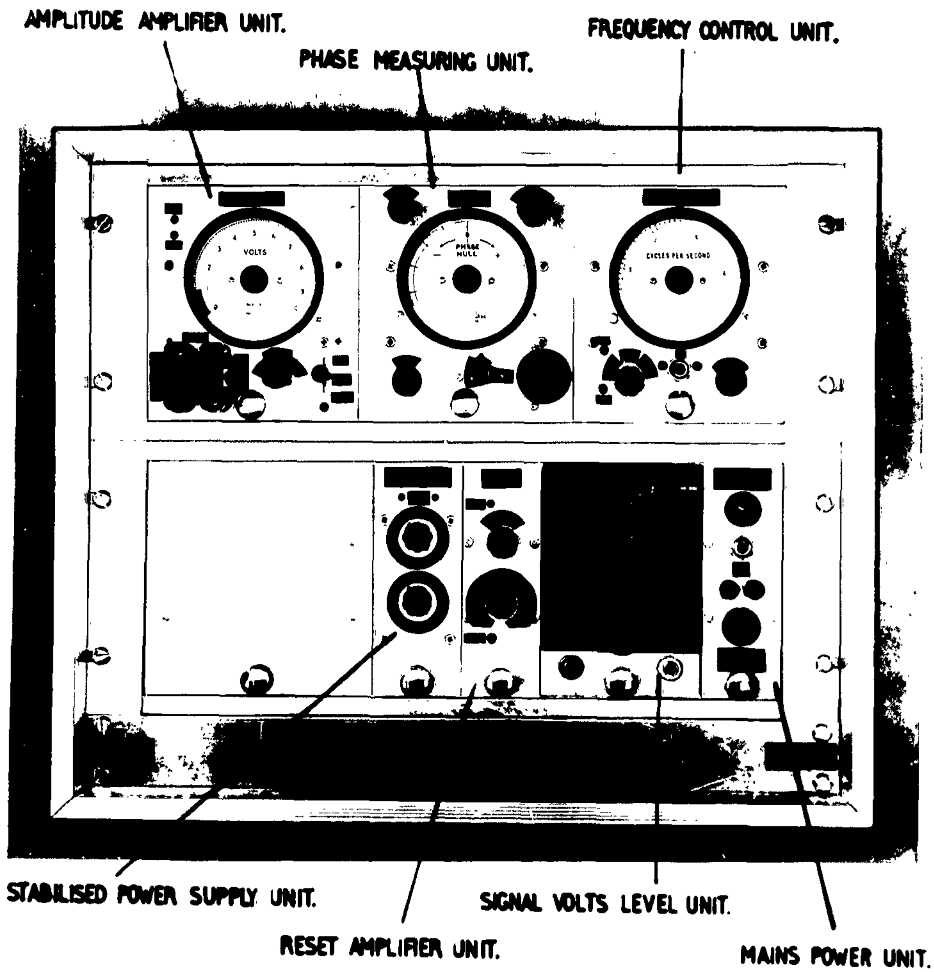

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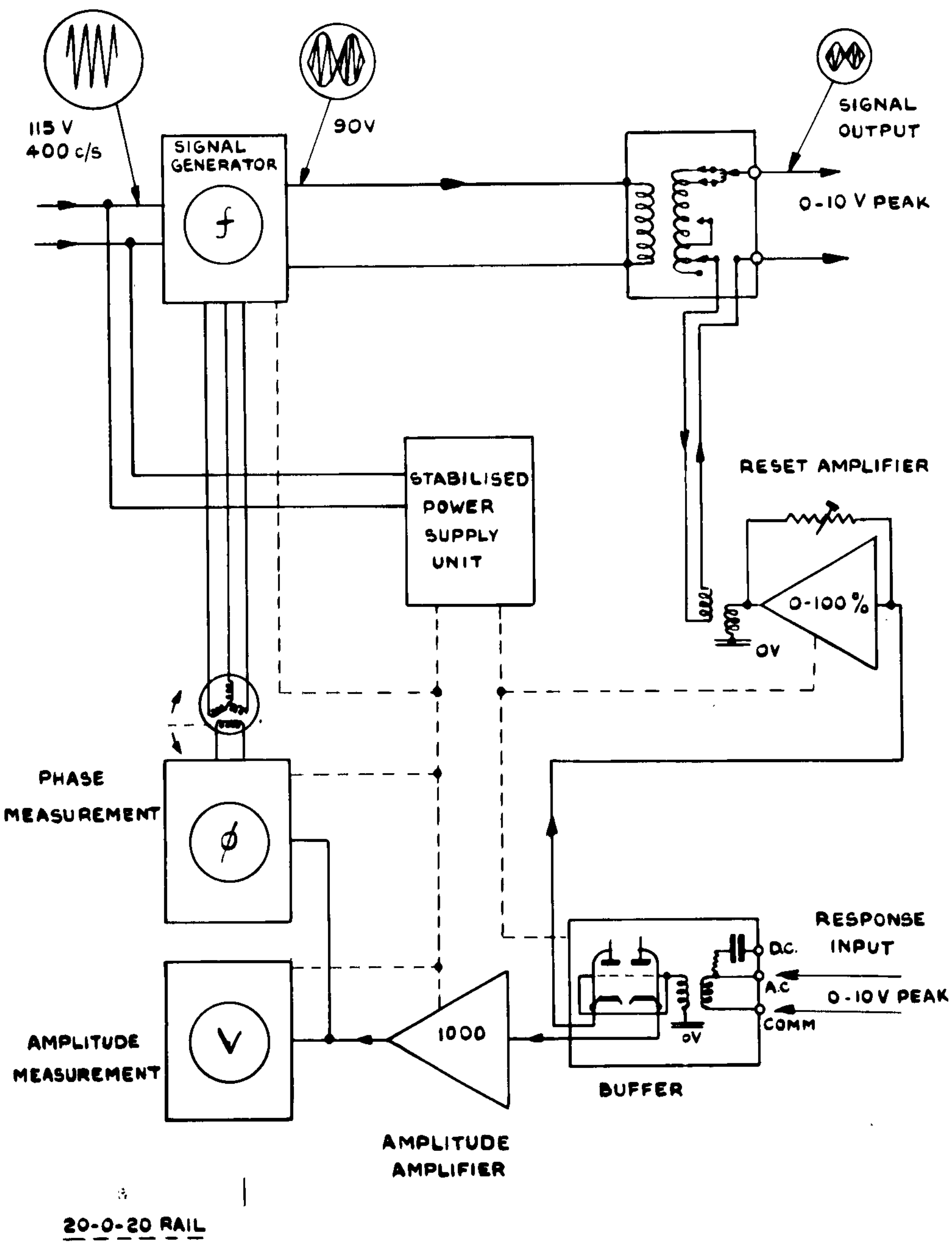
FIG. 2.

HARMONIC RESPONSE TESTER.

SCHEMATIC DIAGRAM



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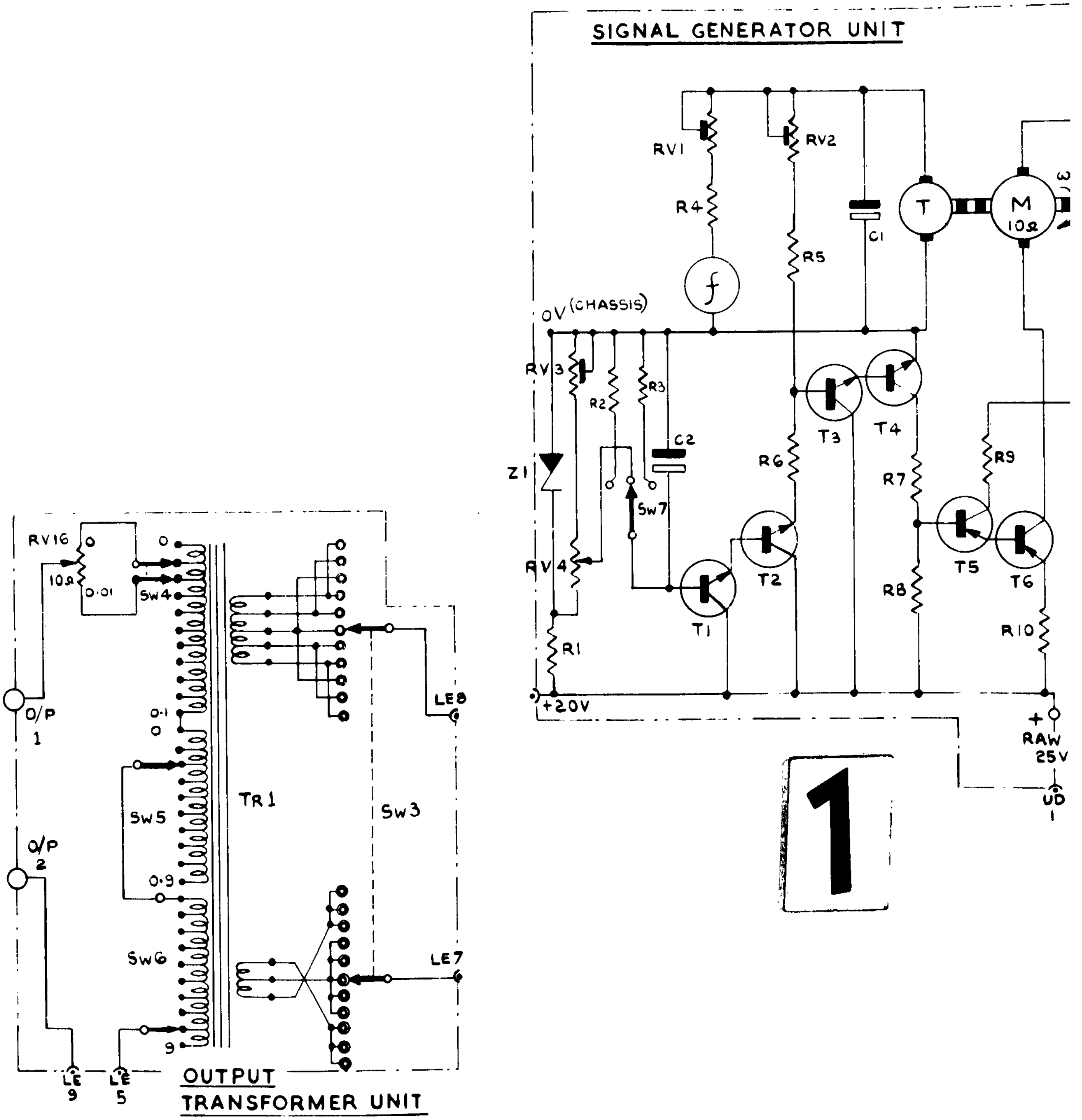
HARMONIC RESPONSE TE

SIGNAL GENERATOR

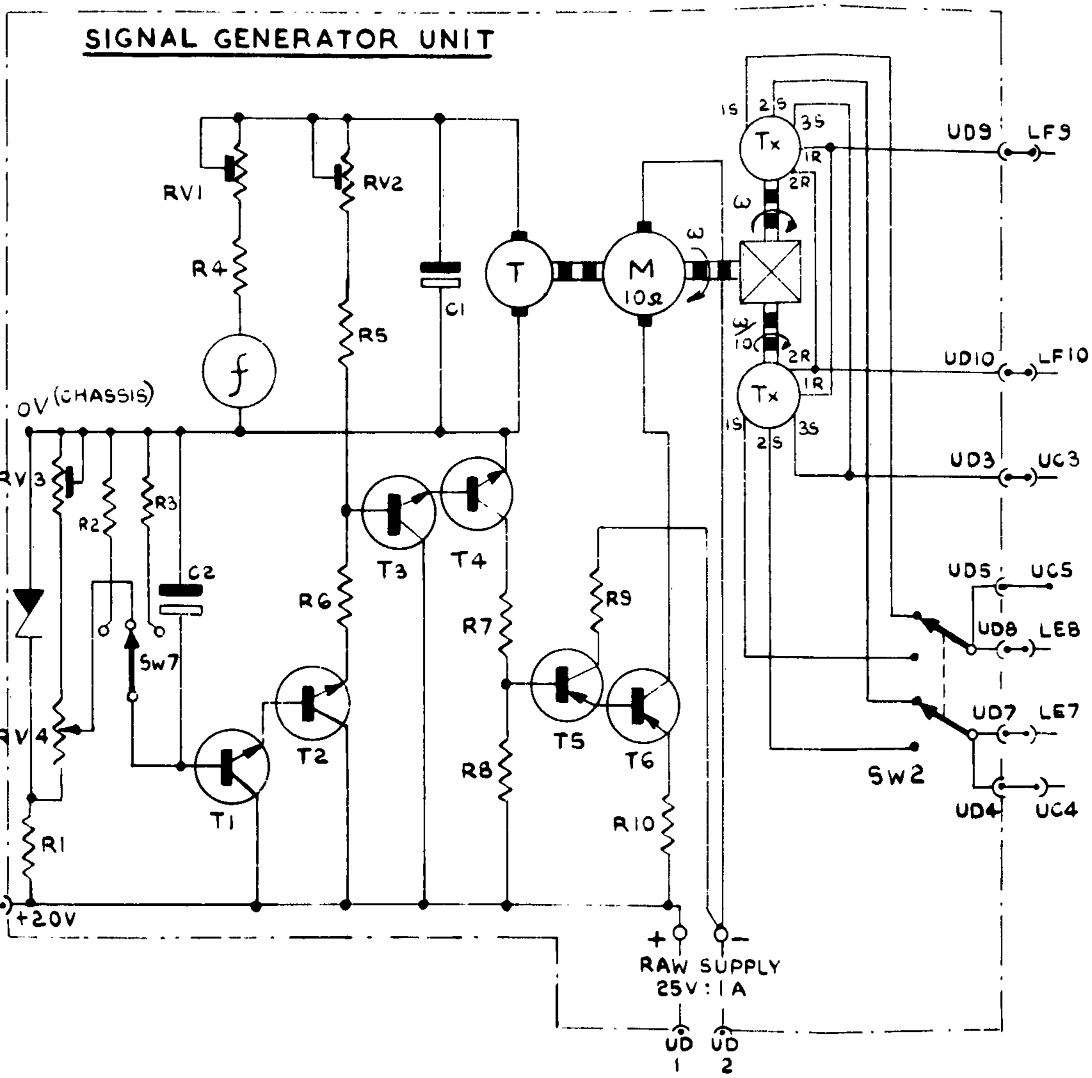


1

FIG. 3.

HARMONIC RESPONSE TESTER

SIGNAL GENERATOR



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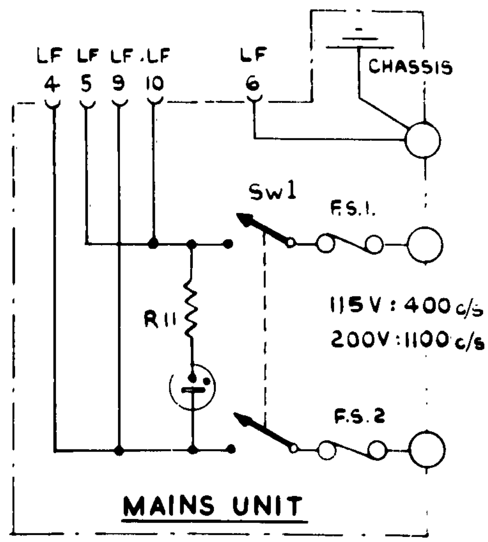


HARMONIC RESPONSE TESTER

RESET AMPLIFIER

1

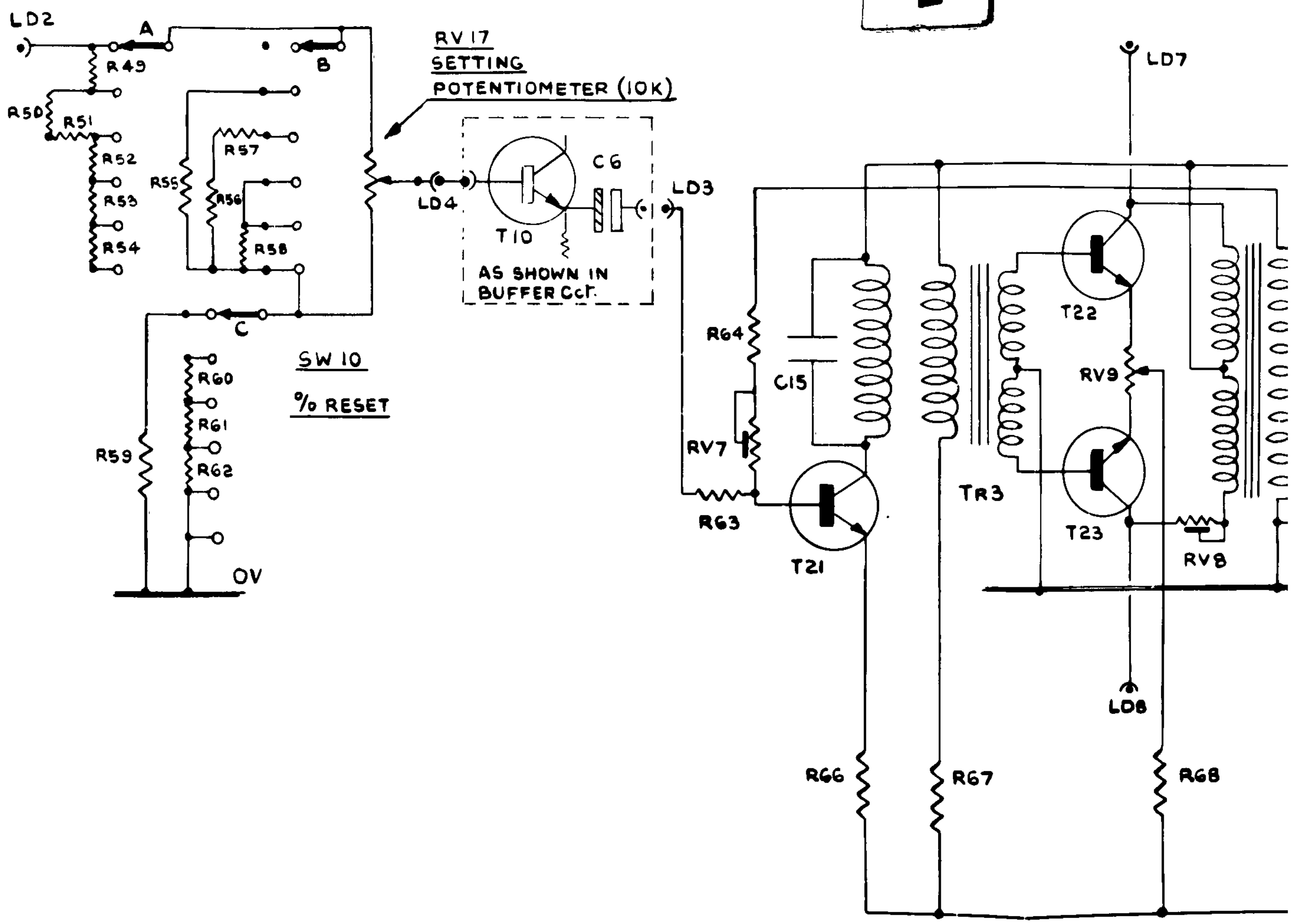
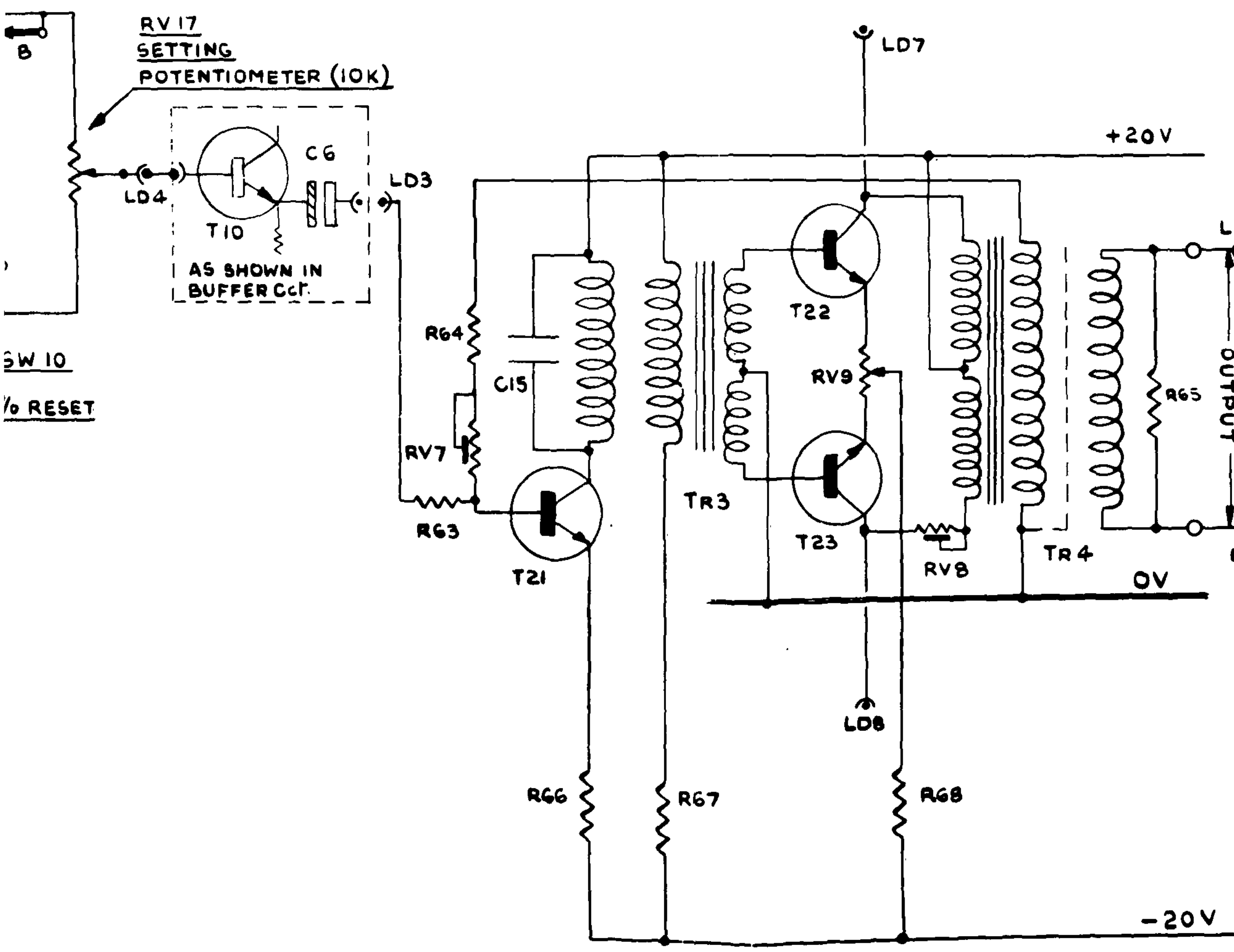


FIG. 4.

HARMONIC RESPONSE TESTER

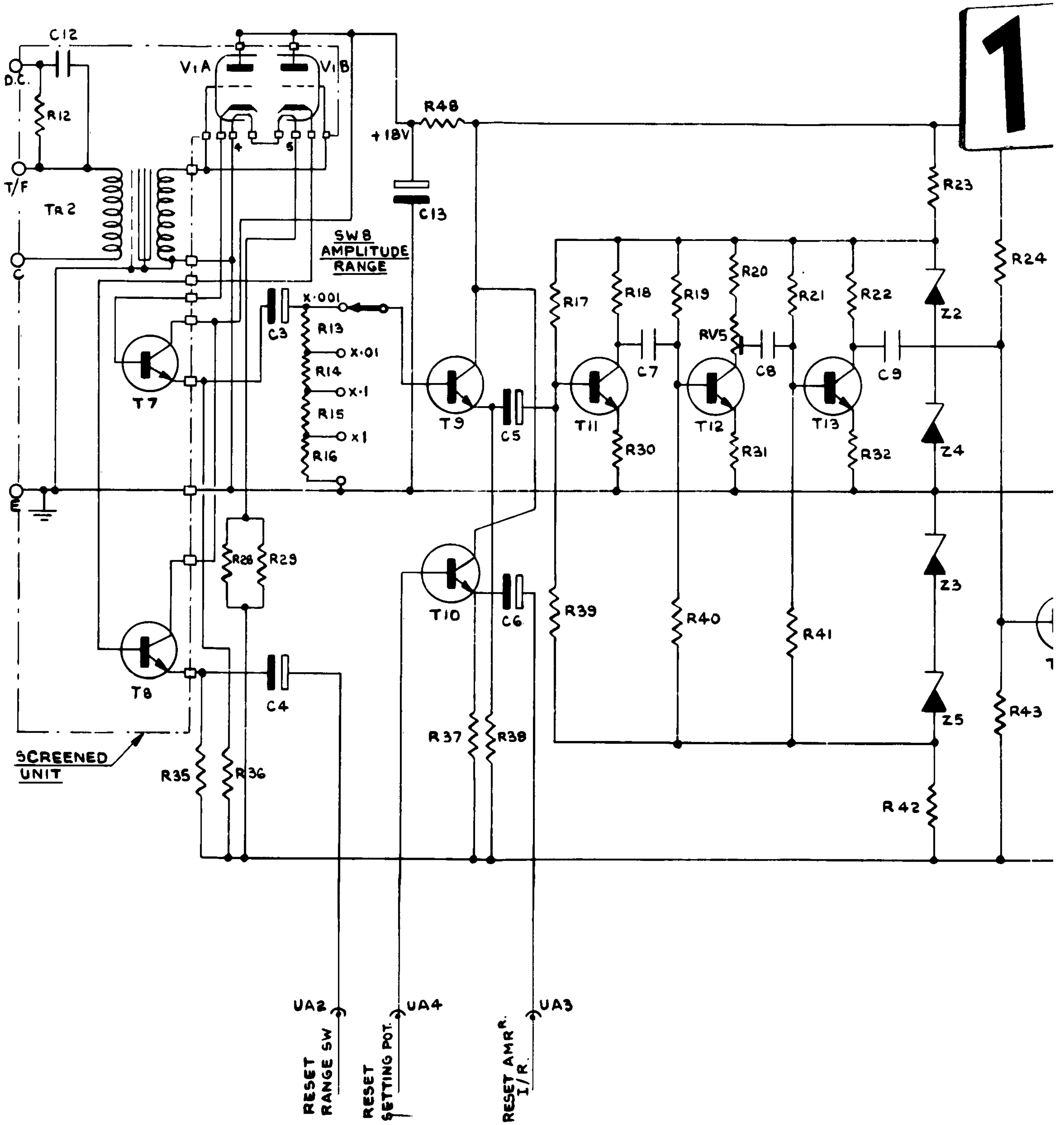
RESET AMPLIFIER

2



HARMONIC RESPONSE

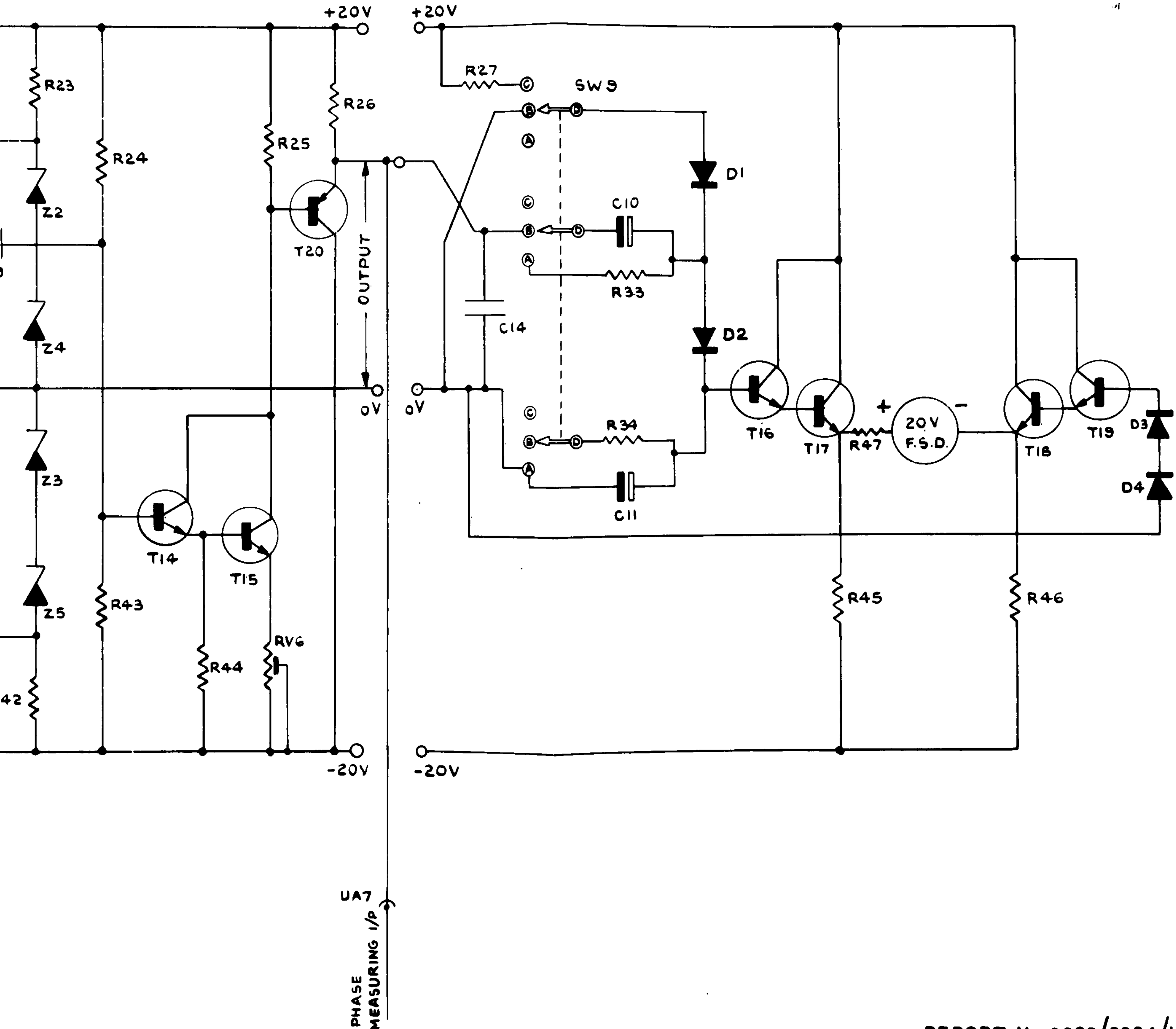
AMPLITUDE AMPLIFIE



RESPONSE TESTER.

UDE AMPLIFIER

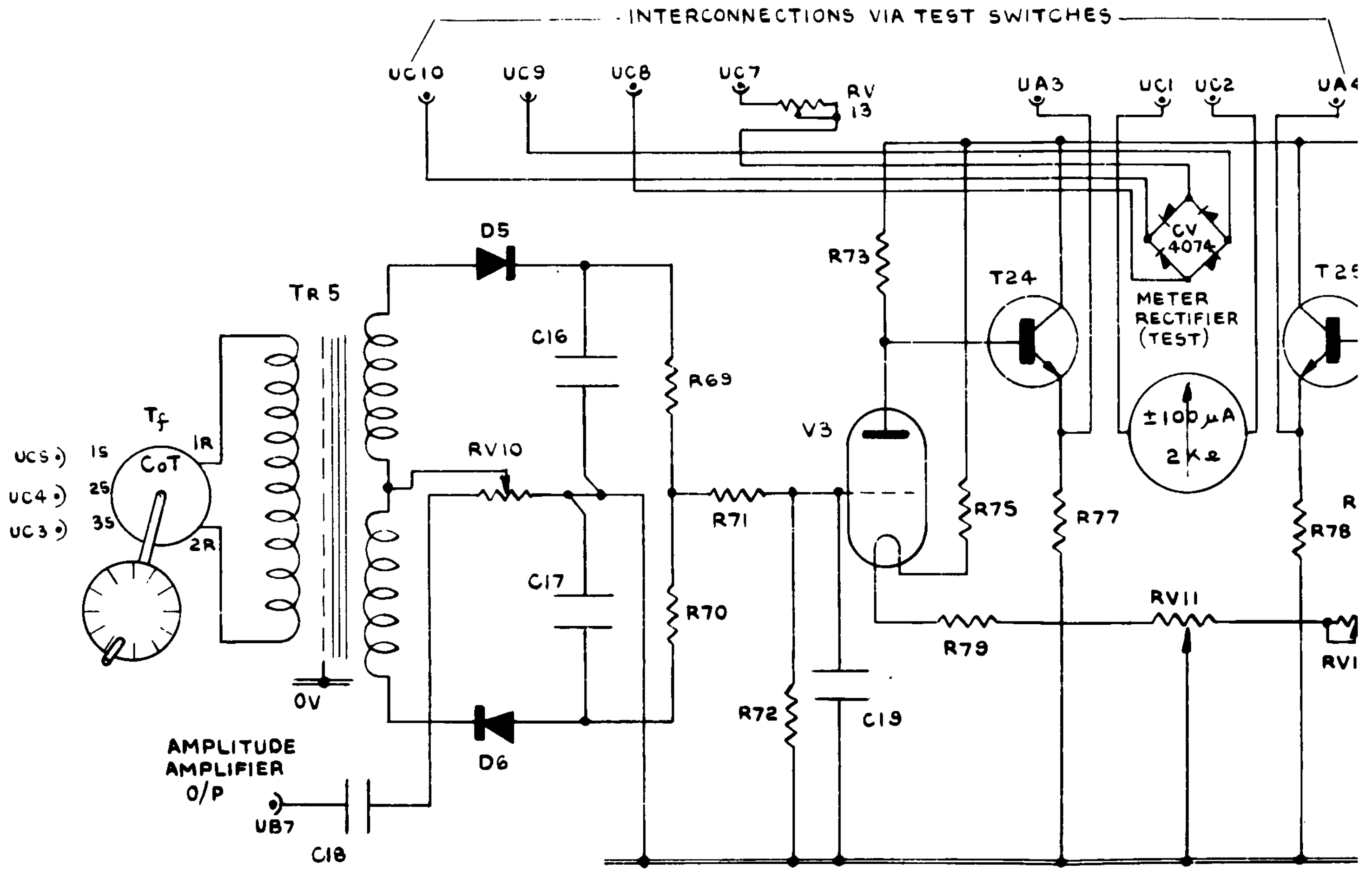
2



HARMONIC RESPONSE TESTER

PHASE MEASURING UNIT

1



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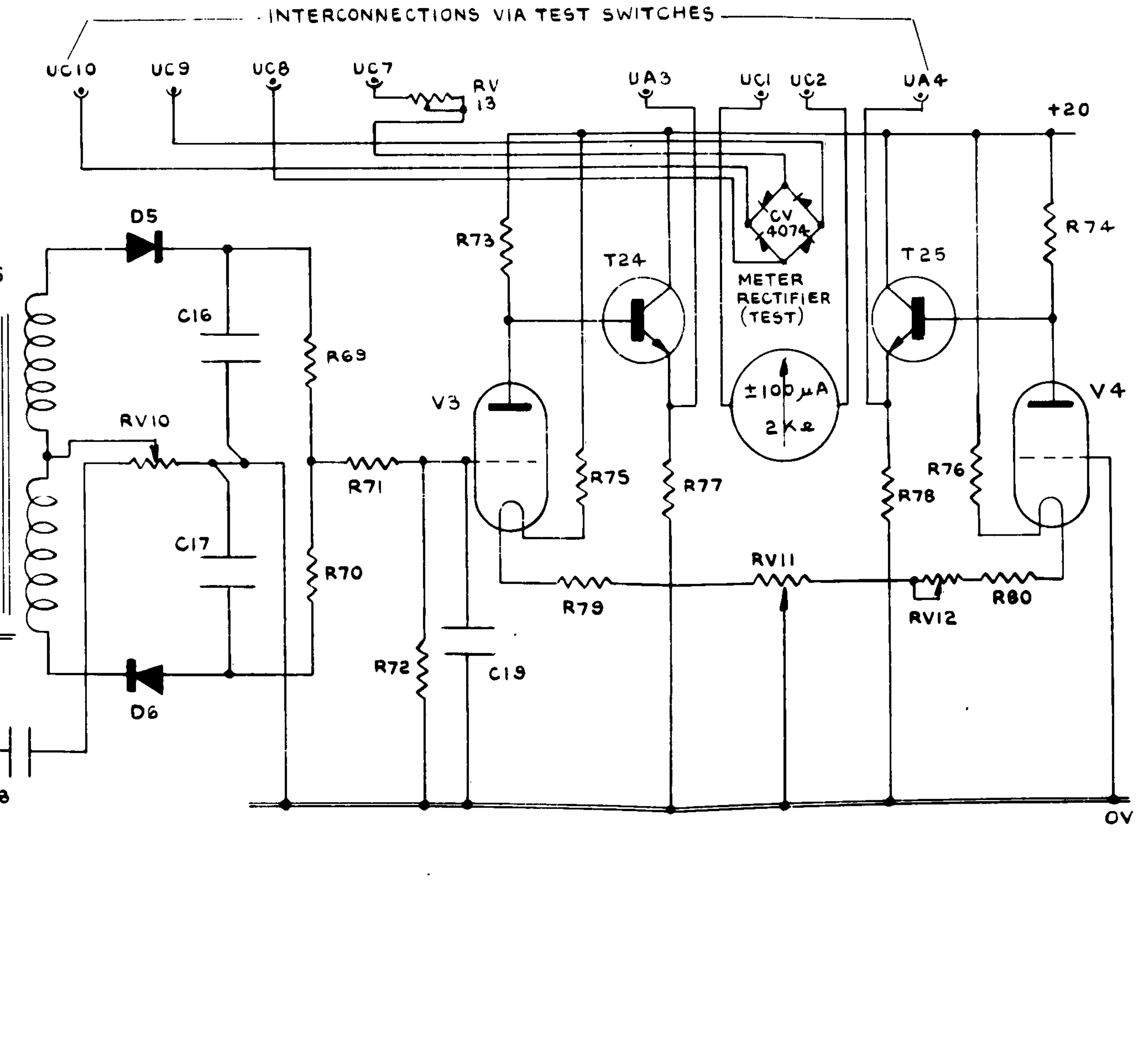
PHASE MEASURING UNIT

2



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HARMONIC RESPONSE TESTER

POWER SUPPLY UNIT

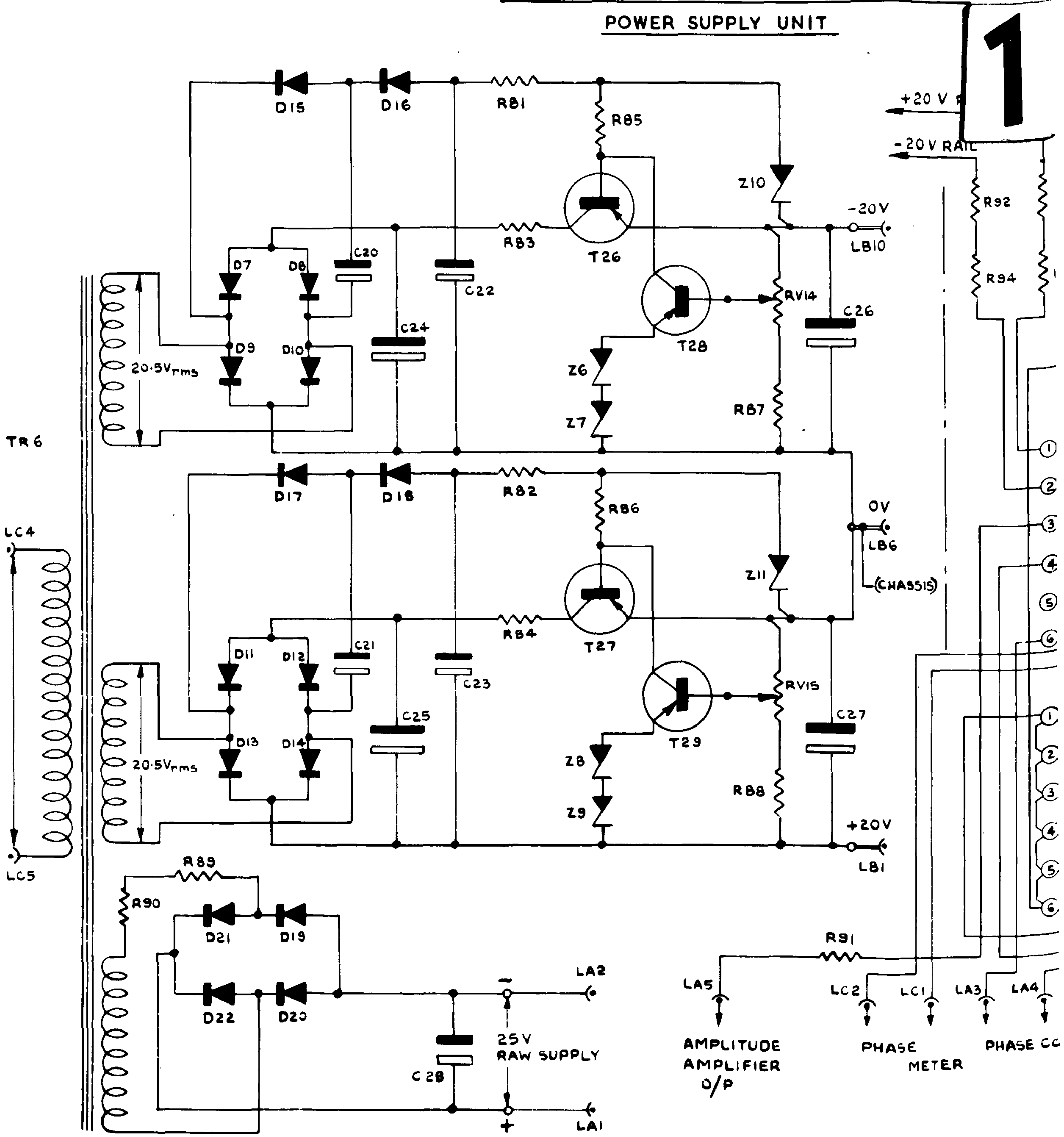
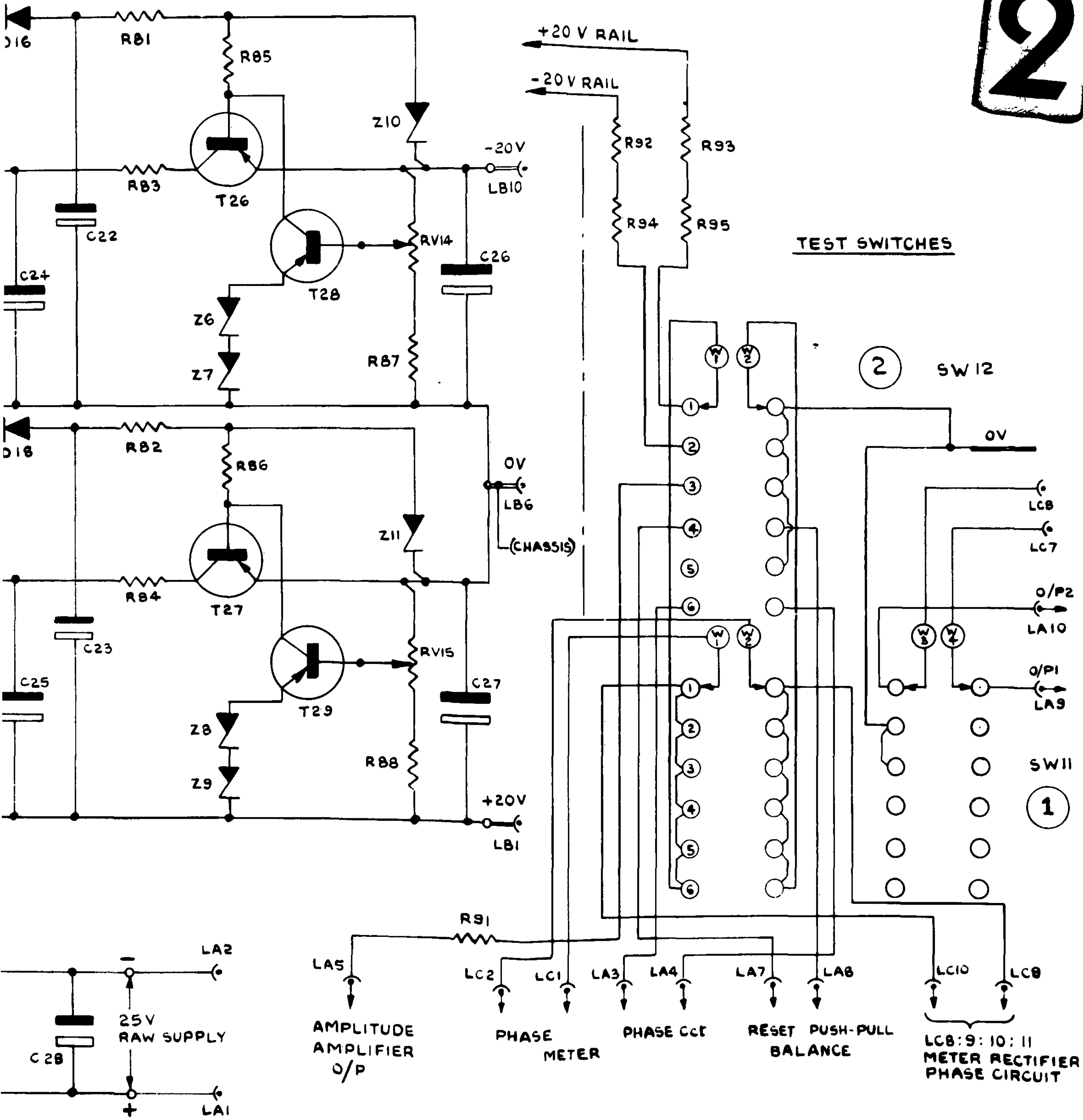


FIG. 7.

HARMONIC RESPONSE TESTER

POWER SUPPLY UNIT

2



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Date of Search: 31 July 2008

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Former reference (Department) Report No. 2383
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