ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

SPINNING DISK ELECTRONIC RANDOM SELECTOR

Technical Memorandum No. 39

Electronic Defense Group
Department of Electrical Engineering

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Approved by: A. B. Macnee

Project 2262

TASK ORDER NO. EDG-3
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ERRATA

TECHNICAL MEMORANDUM NO. 39

Page No.

iii Figure 4, Change "slide" to "side."

7 Paragraph 1, Line 5 Change "condensors" to "condensers."

7 Paragraph 6, Line 1 Change "condensors" to "condensers."

10 Figure 7 - Diagram Changes:
Insert a resistor R-98 100k 1/2 w in series with the lead to pin 2 of V-9a.
Similarly insert a resistor R-99 100k 1/2 w in series with the lead to pin 7 of V-10b.
Near V-8, right in middle of page:
Leads 1 through 9 on S-3 are incorrectly connected to V-8.
Following is a drawing of the corrections:

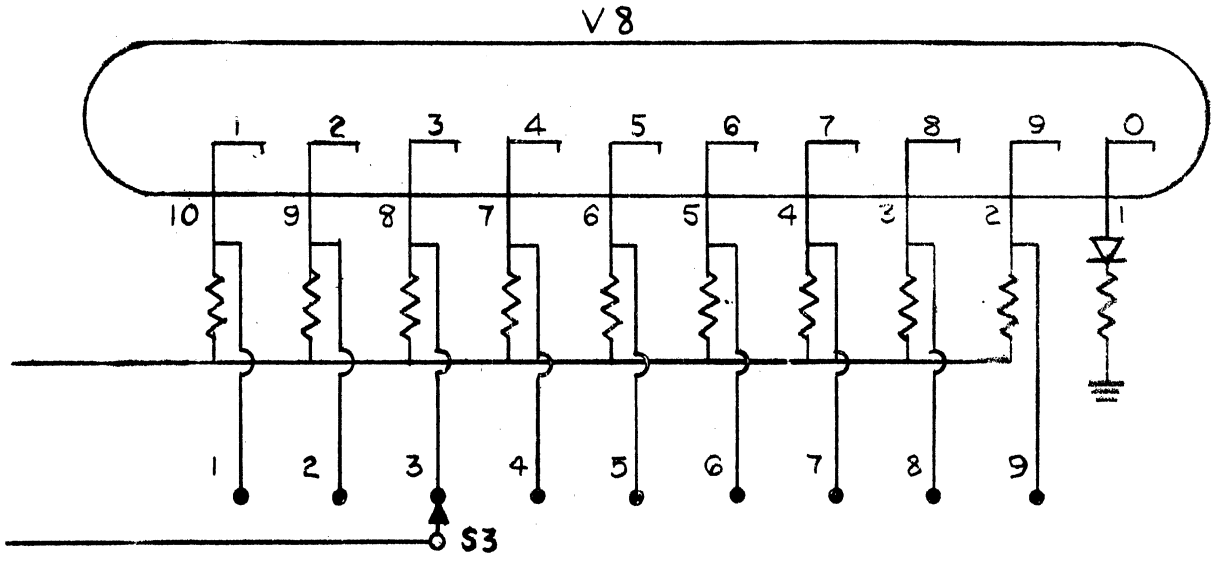


Figure 7 - Parts List Changes:

R-64	Change 2.2k to 2.7k
R-67	Change 2.2k to 2.7k
R-97	Add R-98, R-99 along side R-97
C-30	Following C-30 insert: C-31 0.1 µfd 600 VDC paper
V-15	Following V-15 insert: D_1, D_2, D_3 1N39
T-1	Change P-8408 to PC-8408
T-2	Change P-8401 to PC-8401
L-1	Change P-1001 to C-1001
L-2	Change P-1003 to C-1003
PL-2	Change "Blue" to "Bulb"

ERRATA
TM 39 (continued)

Page s

14 Figure 11 - Diagram Changes:

Near V-1, Left middle of page
Connect the left side of C-3 to pin 6 (plate) of V-1 and dis-
Connect the left side of C-3 from pin 7 (grid).

Near V-6, Left middle of page
Delete C-15 and replace R-27 with a wire.

Near "question switch," top middle of page - change label "S_2" to "J_1"

Near T-1, Right top of page
The center tap of T-1 should not be grounded. Instead the center
Tap should be connected to the junction of L-2 and C-12.

Near V-9 and V-11, Right bottom of page
The cathodes on V-9 and V-11 labeled "1,2,6,8" should be labeled
"1".

Figure 11 - Parts List Changes:

R-21	Change 10 W to 25 W
R-27	Delete
R-52	Replace "not used" with "10K"
C-15	Delete
T-1	Change PC-8408 to PC-8402
T-2	Change PC-8402 to PC-8408
S-2	Change S-2 to J-1
	Following "IA-2" add "or A-2"
NE	Change 147-1112 to 147-1144

15 D.C. Supply Voltages
Change "measures" to "measured"

23 Waveform (t) under Notes
Change "hundreds 0" to "hundreds 1"

26 Table 3, under Resistors
Change "2 2.2K 1/2w" to "2 2.7K 1/2w"
Change "7 100K 1/2w" to "9 100K 1/2w"

27 Table 3, under Condensers
Add "1 0.1 µfd 600 VDC paper"
Table 3, under Tubes
Add "DIODES"
"3 1N39"
Add "MISCELLANEOUS"
"See Page 10, Figure 7 Parts List."

28 Table 4
Delete "1 5.6k 1/2w"
Change "3 10k 1/2w" to "4 10k 1/2w"
Change "10 watt Dividohm" to "25 watt Dividohm"
Delete "1 0.1µfd 400 VDC metalized"

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABSTRACT

A three decade spinning disk electronic random selector or number generator is described. The number selections are equally likely and the modulus is adjustable from 10 to 1000 in increments of 10.

SPINNING-DISK ELECTRONIC RANDOM SELECTOR

1. INTRODUCTION

This memorandum describes a random selector for generating random numbers that are equally-likely. The modulus of the random selector can be adjusted from 10 to 1000 in increments of 10.

2. EQUIPMENT DESCRIPTION

Photographs of the complete unit are shown in Figures 3-6. This random selector has three decade counters for reading out the selected number and one neon bulb indicator for an equally-likely binary output. The selection of a number is obtained by depressing the Q-switch (Question-Switch).

The principle of operation of this random selector is as follows: An electronic counter of modulus N is driven continuously by a recurrent pulse generator. This means that the counter will be in each of its N possible states the same length of time. Therefore, each number is equally-likely. The Q-switch is placed between the pulse generator and the counter so that the counter can be stopped when a selection is desired. Randomness is obtained by operating the counter at a relatively high rate with respect to the period between operations of the Q-switch. Anything that operates the Q-switch, such as a human operator, will have some variance in its timing. If this variance is large with respect to the period for one cycle of modulus N, then independence of number selections is obtained.

3. CIRCUIT DESIGN

A basic block diagram of the spinning disk random selector is shown in Figure 1. This illustration shows the recurrent pulse generator, the gate circuit or Q-switch, and the counter and readout circuit of modulus N. To facilitate reading the schematic diagram a more detailed block diagram of the equipment is shown in Figure 2.

The random selector described here was designed to meet the following requirements. (1) The questioning of the equipment would be manual and occur no faster than once per second. (2) The maximum modulus of the counter should be 1000 and should be adjustable from 10 to 1000 in increments of 10. (3) The counter should use cold cathode counter tubes because of the low cost, small size, low power requirements, and direct readout. (4) In addition to the modulus N selection, an equally-likely binary output should be provided.

The use of cold cathode counter tubes sets an upper limit to the operating speed of the counter. The type GC-10-D tube, which is a decade counter, has a maximum counting rate of 20 kc, and thus has an output of 2 kc. The GC-10-D does not have separate pin connections for each cathode; therefore, it cannot be used as a preset counter. The GS-10-C has separate cathodes but is limited in counting speed to 4 kc. Thus the maximum counting speed can be achieved by using one GC-10-D and two GS-10-C tubes. This arrangement will also allow the desired modulus adjustment.

The independence of number selections is a result of operator timing variation. Relative to a starting time (t_o) the operator timing variation will have a peaked probability density curve. In order to obtain equally-likely number selections, the probability of the operator stopping the counting process in an interval (Δt) in the modulus cycle must be the same for any (Δt) in the

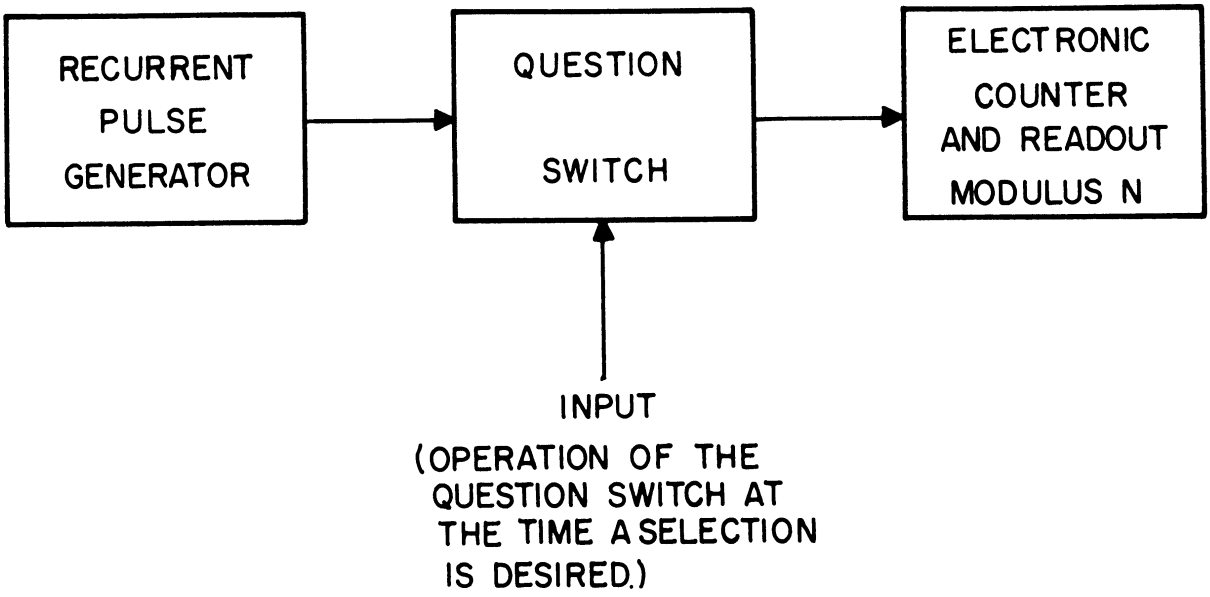


FIGURE 1. BASIC BLOCK DIAGRAM OF THE SPINNING DISK RANDOM SELECTOR

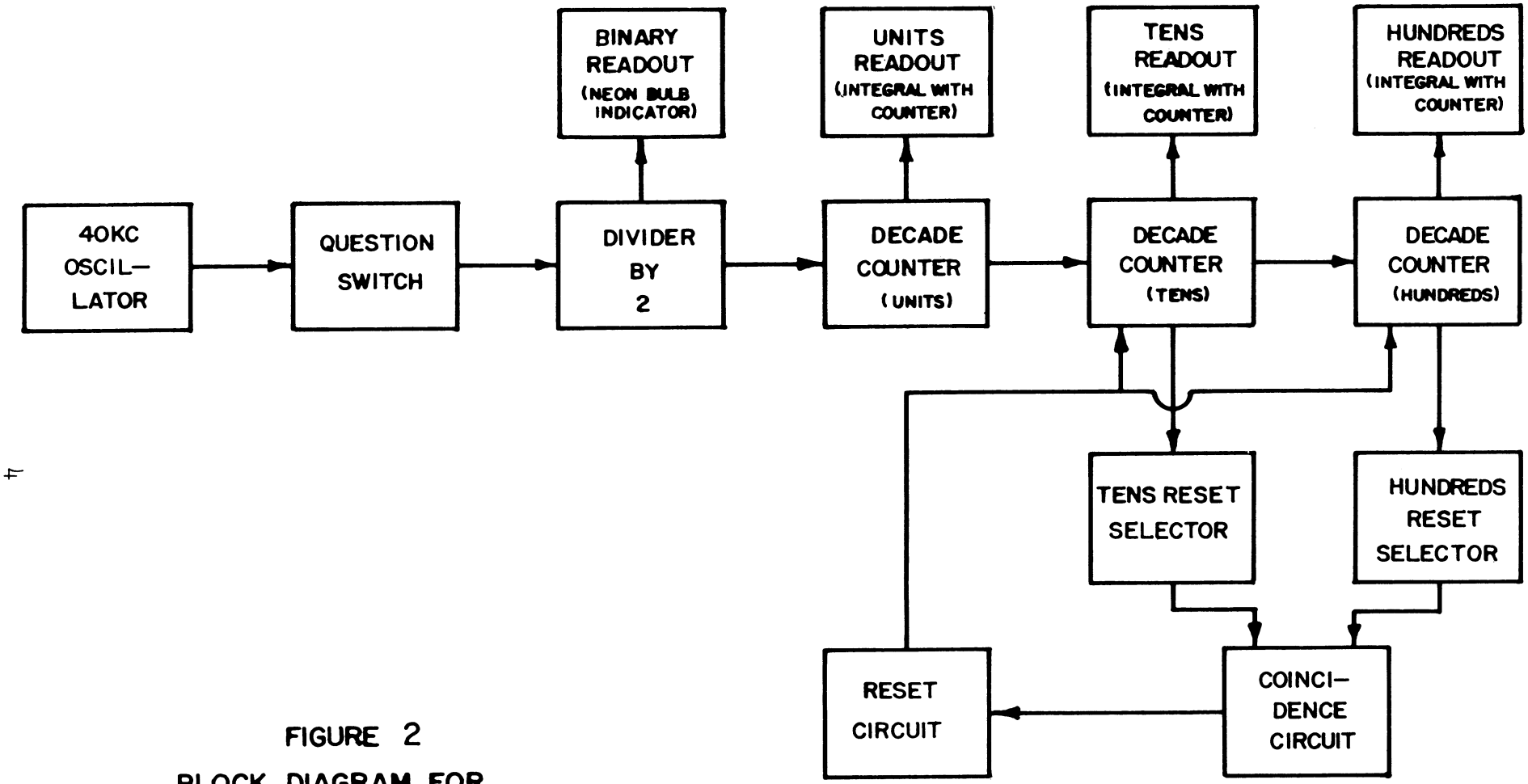


FIGURE 2

BLOCK DIAGRAM FOR

ELECTRONIC RANDOM SELECTOR,

SPINNING DISK TYPE "C",

MODEL I.

modulus cycle. Since the counting process is cyclic the probability density of operator timing variation will be segmented into periods equal to the modulus period. If the modulus period is made short relative to the period between requests for random numbers and is less than or equal to the standard deviation (σ_o) of the operator timing variation, then the addition of the segments of the probability density curve will result in an approximately uniform distribution over the modulus period. This segmenting and addition of the segments of a probability density curve is known as the wrap-around effect. Birdsall has calculated the peak-to-peak difference to be 1% of the peak wrap-around probability density when the modulus period equals 1.6 times the standard deviation of the operator timing.[1]

For this particular counter, which has a maximum modulus of 1000, the maximum modulus period is 0.05 second. If a criterion of 1% variation in wrap-around probability density is selected, then the smallest σ_o should be 0.03 second.[2] Any σ_o larger than 0.03 second will result in a more uniform wrap-around probability density.

If a "safety factor" is desired the operator of the equipment should not watch the counter tubes prior to actuating the Q-switch, since timing information can be obtained from the hundreds counter. The result of receiving this information may be a reduction in σ_o.

The modulus of the counter is set by two switches. The switches select one cathode on the tens counter and one on the hundreds counter. The outputs from the switches are applied to a coincidence circuit such that when a voltage exists between both the selected cathodes and ground the counter is forced to reset. Thus, any modulus between 10 and 1000 in increments of 10 may be obtained.

1. If N is the modulus, $p\ (\text{each number}) = \frac{1}{N} \pm .005\ \frac{1}{N}$

2. Experiments by the writer have shown that for a human operator to count "1/1000", "2/1000" takes about 1.5 seconds with a σ_o of about 0.40 seconds.

The output of the binary unit is applied to the modulus N counter. A GC-10-D counter is used for the units decade.[1] All cathodes except the output cathode are tied together in this tube; therefore, only decade counting can be obtained. The output indicator is an integral part of the counter and is a gaseous discharge glow that can appear in one of ten different positions on a circular path. The angular position indicates the count. The output cathode and resistor produce one output pulse for every ten input pulses to the counter. This pulse is coupled to the input of the next counter. The physical orientation of the tube relative to the bezel should be such that the output cathode lines up with the "0" on the bezel.

The tens and hundreds counters are identical to each other and are similar to the units counter. The primary difference is that the tens and hundreds counters have a lower counting speed (4 kc) and all cathodes are brought out separately. A cathode is illuminated by a current flowing through it and a voltage drop is developed across the cathode resistor. Since all cathodes are brought out separately, and each one has a separate resistor, the location of the cathode glow can be identified by the presence of a voltage. This provides a convenient method for identifying the state of the counter. In this particular application an eleven position switch is used with the tens and hundreds counters to select the cathodes that trigger the automatic reset circuit. As mentioned above, when coincidence of these two switch outputs occurs, the tens and hundreds counters are reset to "0". The coincidence circuit drives a reset circuit in order to provide a sufficiently long reset pulse. The reset circuit is a multivibrator followed by a reset amplifier for the tens counter and one for the hundreds counter. Since the reset circuit insures that resetting goes to completion there is no bias towards the last number in the modulus or 000.

1. This tube may be obtained from the Atomic Instrument Company of Cambridge, Massachusetts.

4. EQUIPMENTS AND CIRCUITS

Photographs of the Electronic Spinning Disk Random Selector (Type "C", Model 1) are shown in Figures 3, 4, 5, and 6. The complete circuit diagram is shown in Figure 7. The voltages and resistances at important points are tabulated in Table 1. Typical waveforms are shown in Table 2. Quantities, values and types of resistors, condensors and tubes are shown in Table 3.

The 460 and 420 volt busses are nominal values. The exact settings of these voltages will depend on the average ac line voltage and the particular counter tubes in the equipment. The equipment may be expected to operate with 30% variation in the line voltage with new tubes.

Photographs and circuits for two similar random selectors are also included in this report. One of these is a single decade portable unit and the other is a three decade rack-mounted random selector. The three decade random selector does not have an adjustable modulus but does have an automatic circuit for displaying the random number for a time and then returning to the counting cycle.

A photograph of the single decade random selector is shown in Figure 8. The circuit for this unit is shown in Figure 9. This is designated as Electronic Spinning Disk Random Selector, Type "C", Model 3.

Photographs of the three decade rack-mounted random selector are shown in Figure 10. The circuit for this selector is shown in Figure 11. The designation of this unit is Electronic Spinning Disk Random Selector, Type "C", Model 2.

Quantities, values and types of resistors, condensors and tubes are shown in Table 4.

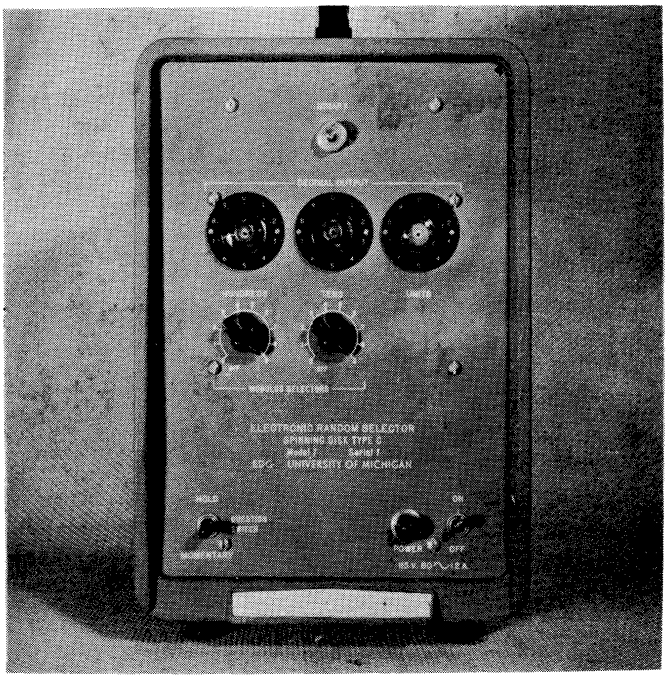


FIG. 3. FRONT VIEW OF THE SPINNING DISK RANDOM SELECTOR, TYPE "C", MODEL I.

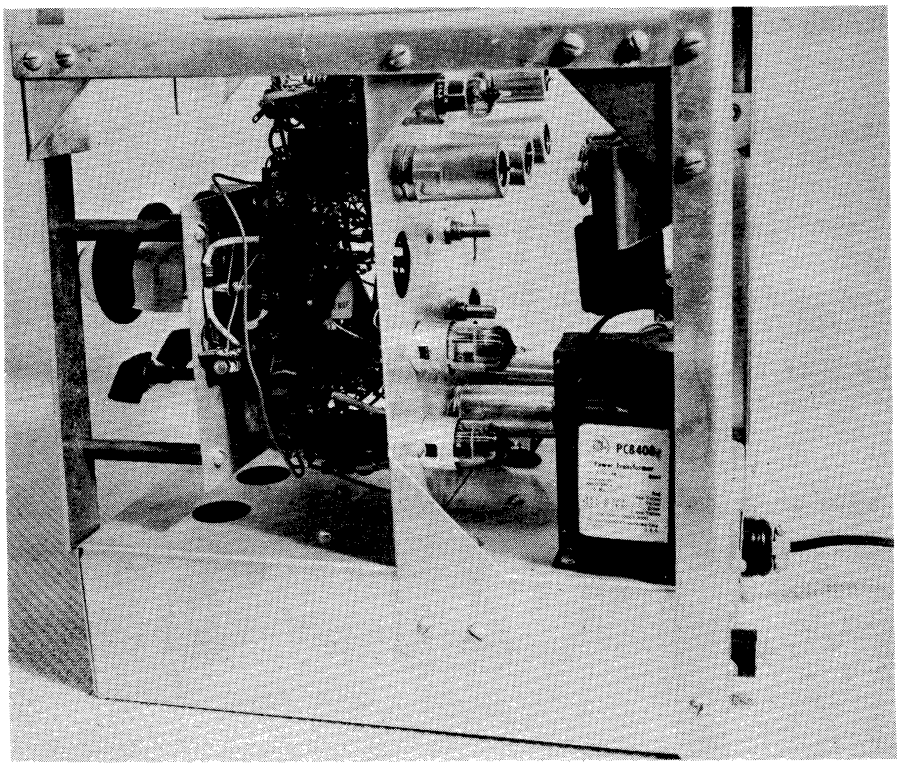


FIG. 4. SIDE VIEW OF CHASSIS.

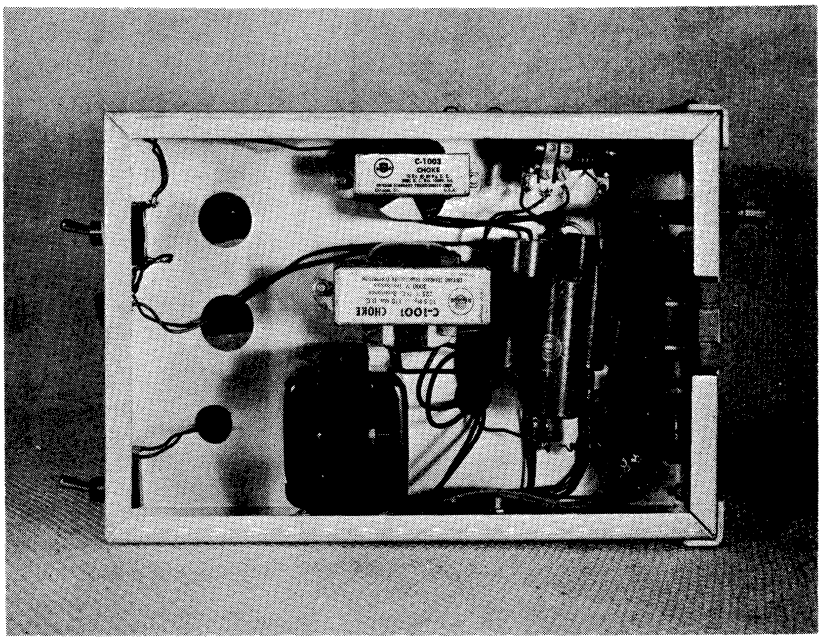


FIG. 5. BOTTOM VIEW OF CHASSIS

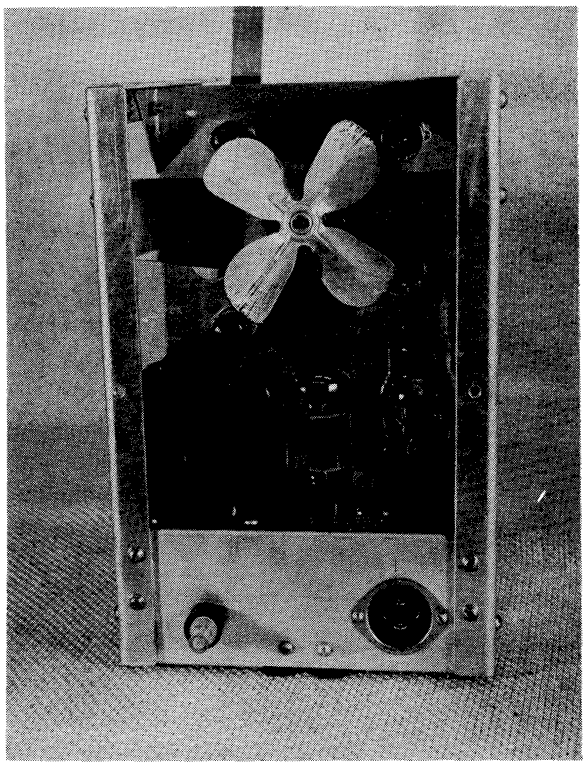


FIG. 6. BACK VIEW OF CHASSIS

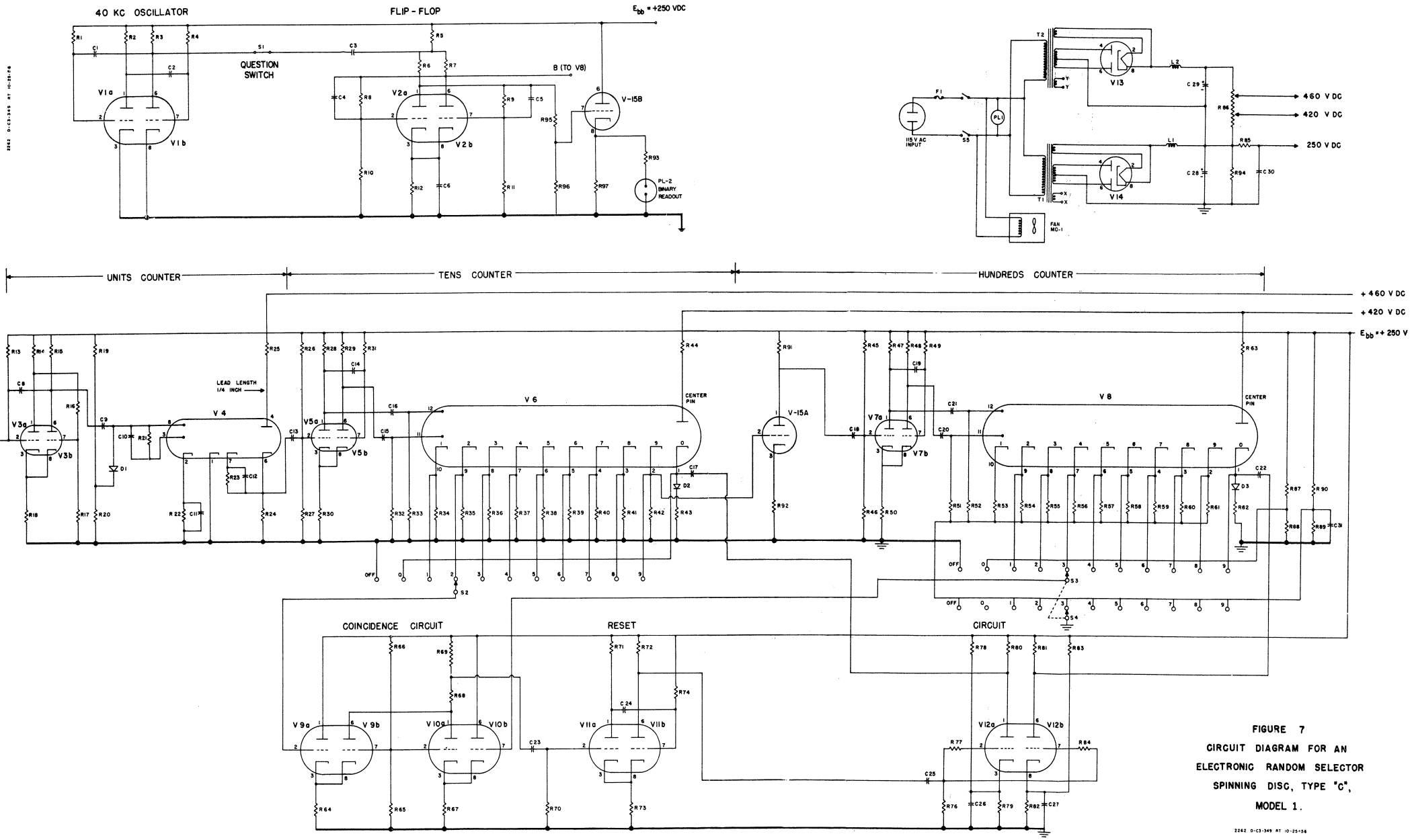


FIGURE 7
CIRCUIT DIAGRAM FOR AN ELECTRONIC RANDOM SELECTOR SPINNING DISC, TYPE "C", MODEL 1.

2262 D-C3-349 RT 10-25-56

Note–See reverse side for PARTS LIST

Resistors

R1	1 meg	1/2 w
R2, 3	47 k	2 w
R4	1 meg	1/2 w
R5, 6, 7	47 k	1 w
R8, 9	270 k	1/2 w
R10, 11	100 k	1/2 w
R12	12 k	1/2 w
R13	1 meg	1/2 w
R14, 15	100 k	1 w
R16	680 k	1/2 w
R17	82 k	1/2 w
R18	10 k	1/2 w
R19	270 k	1/2 w
R20	56 k	1/2 w
R21, 22, 23	220 k	1/2 w
R24	68 k	1/2 w
R25	330 k	1/2 w
R26	22 meg	1/2 w
R27	820 k	1/2 w
R28, 29	100 k	1 w
R30	10 k	1/2 w
R31	1 meg	1/2 w
R32	330 k	1/2 w
R33	390 k	1/2 w
R34, 35, 36, 37 38, 39, 40, 41, 42, 43	68 k	1/2 w
R44	470 k	1/2 w
R45	22 meg	1/2 w
R46	820 k	1/2 w
R47, 48	100 k	1 w
R49	1 meg	1/2 w
R50	10 k	1/2 w
R51	330 k	1/2 w
R52	390 k	1/2 w
R53, 54, 55, 56, 57, 58, 59, 60, 61, 62	68 k	1/2 w
R63	470 k	1/2 w
R64	2.2 k	1/2 w
R65	33 k	1/2 w
R66	470 k	1/2 w
R67	2.2 k	1/2 w
R68, 69	47 k	1 w
R70	100 k	1/2 w
R71, 72	100 k	1 w
R73	10 k	1/2 w
R74	3.3 meg	1/2 w
R75	Does not exist.	
R76	1 meg	1/2 w
R77	100 k	1/2 w
R78	56 k	2 w
R79	5.6 k	1/2 w
R80,81	100 k	1 w
R82	5.6 k	1/2 w
R83	56 k	2 w
R84	100 k	1/2 w
R85	1 k	10 w
R86	15 k	25 w
R87	680 k	1/2 w
R88	68 k	1/2 w
R89	1 meg	1/2 w
R90	470 k	1/2 w
R91	100 k	1 w
R92	68 k	1/2 w
R93	100 k	1/2 w
R94	150 k	1 w
R95	1.0 meg	1/2 w
R96	3.3 meg	1/2 w
R97	100 k	1/2 w

Condensers

C1, 2, 3	33 pfd	600 VDC Ceramic
C4, 5	47 pfd	600 VDC Ceramic
C6	5000 pfd	600 VDC Ceramic
C7	15 pfd	600 VDC Ceramic
C8	33 pfd	600 VDC Ceramic
C9	500 pfd	600 VDC Ceramic
C10, 11, 12, 13	100 pfd	600 VDC Ceramic
C14	200 pfd	600 VDC Ceramic
C15	300 pfd	600 VDC Ceramic
C16	1000 pfd	600 VDC Ceramic
C17	200 pfd	600 VDC Ceramic
C18	100 pfd	600 VDC Ceramic
C19	200 pfd	600 VDC Ceramic
C20	300 pfd	600 VDC Ceramic
C21	1000 pfd	600 VDC Ceramic
C22	1500 pfd	600 VDC Ceramic
C23, 24, 25	500 pfd	600 VDC Ceramic
C26, 27	1 µfd	200 VDC Metalized
C28, 29, 30	30 µfd	450 VDC Electrolytics

Tubes

V1	12AT7
V2	5963
V3	12AT7
V4	GC-10-D
V5	12AX7
V6	GS-10-C
V7	12AX7
V8	GS-10-C
V9, 10, 11, 12	12AT7
V13, 14	5V4 GA
V15	1/2 12AT7

S 1	Question Switch. This switch should be a slow operating type. An 0.05 second uncertainty in the time of operation is desirable. A switchcraft type 3033L switch can be used. This switch should be modified so that 1 direction is spring return, that is non-locking.
S 2, 3, 4	1 circuit 10 position non-shorting. ntral AB J Section
S 5	t handle DPST. GC 1332
PL1	on bulb pilot light. Johnson type 7-1144. Red Lucite Cap.
FH1	dicating type fuze holder ttlefuse No. 344013
F 1	L. 1.5 Amp
T 1	Stancor P-8408
T 2	Stancor P-8401
L 1	Stancor P-1001
L 2	Stancor P-1003
Cabinet	Hewlett-Packard cabinet used on 211-A Square Wave Generator
MO 1	Hewlett-Packard 314-3
Fan Blade	Hewlett-Packard 314-9
Air Filter	Hewlett-Packard G-46-A
PL 2	Neon Blue Pilot Light. Johnson Type 147-1142. Clear Lucite Cap.

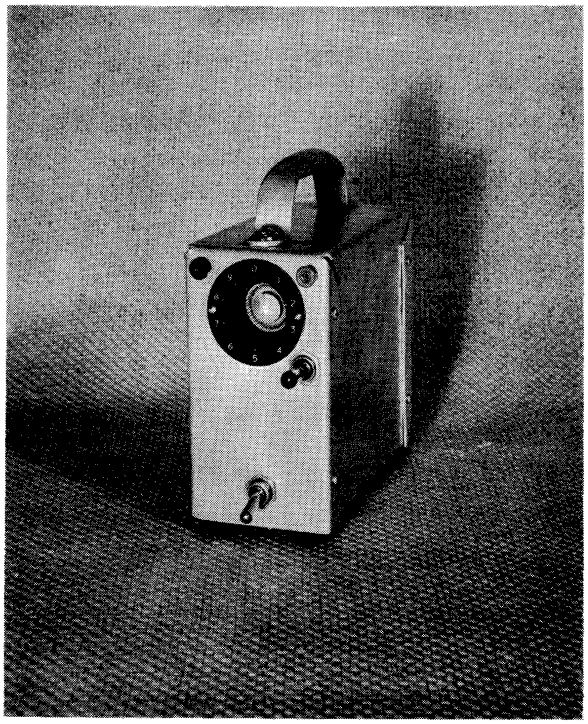


FIG. 8

ELECTRONIC SPINNING DISK RANDOM SELECTOR, TYPE "C", MODEL 3.

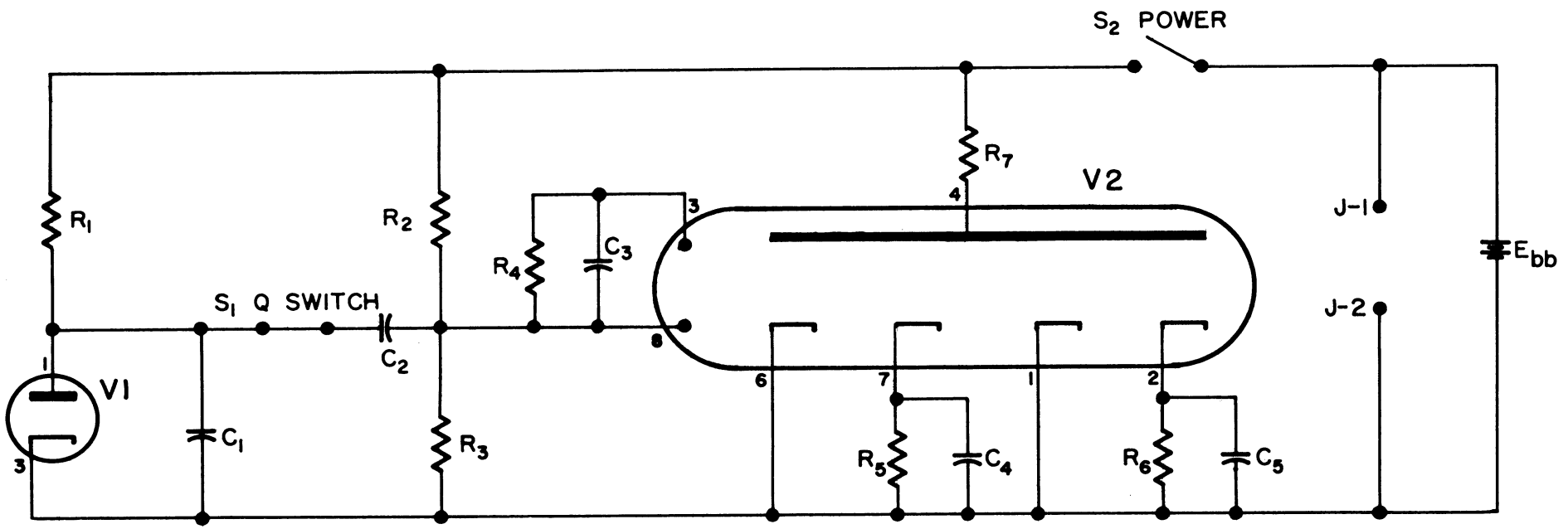


FIG. 9. ELECTRONIC SPINNING DISK RANDOM SELECTOR, TYPE "C", MODEL 3.

	Resistors	
R1	3.3 meg	1/2 w
R2	12 meg	1/2 w
R3	2.2 meg	1/2 w
R4,5,6	220 k	1/2 w
R7	330 k	1/2 w

	Condensers	
C1,2	500 pfd	600 v
C3,4,5	100 pfd	600 v

	Tubes
V1	5823
V2	GC-10-D

Miscellaneous

S-1	Switchcraft 3033L Modified for Momentary and hold Operation.
S-2	Bat Handle SPST GC 1330
E_{bb}	2 - 240 V Stroboflash Batteries in Series Cat. No. 2093

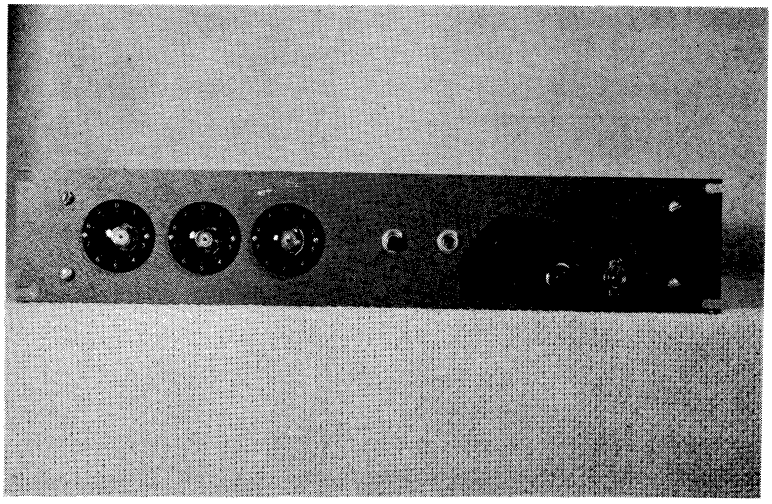


FIG. 10a

ELECTRONIC SPINNING DISK RANDOM SELECTOR, TYPE "C", MODEL 2.

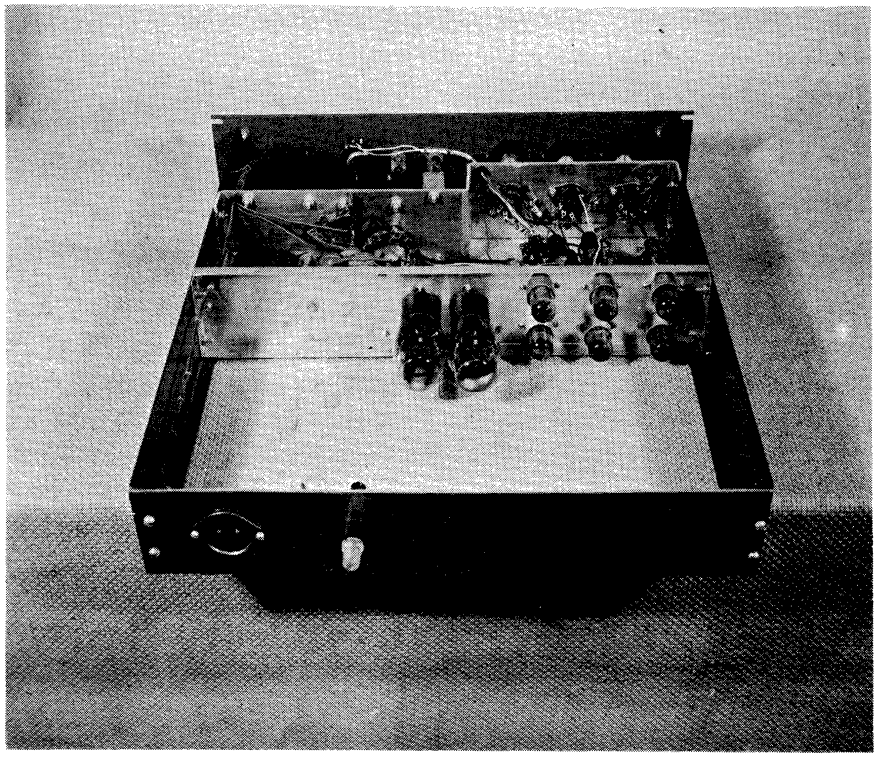


FIG. 10b

BACK VIEW OF CHASSIS.

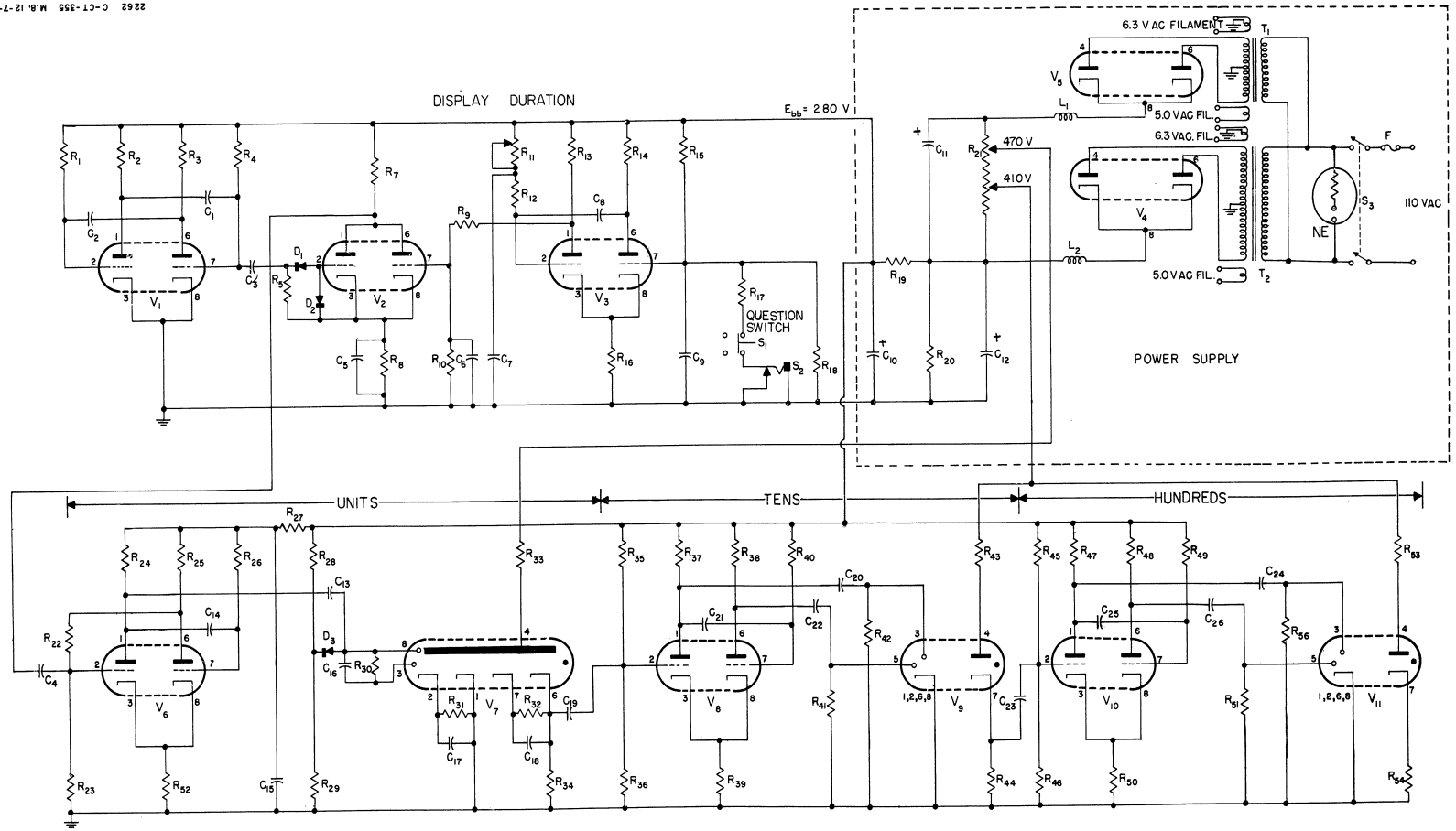


FIG. 11
ELECTRONIC RANDOM SELECTOR SPINNING DISK TYPE C
MOD 2 SERIAL 1

Resistors

R1	1 meg	1/2 w
R2, 3	47 k	1 w
R4	1 meg	1/2 w
R5	100 k	1/2 w
R6	Not used.	
R7	100 k	1 w
R8	47 k	1 w
R9, 10	2.2 meg	1/2 w
R11	5 meg	2 w AB Pot.
R12	1 meg	1/2 w
R13, 14	100 k	1 w
R15	2.7 meg	1/2 w
R16	10 k	1/2 w
R17	100 k	1/2 w
R18	560 k	1/2 w
R19	1 k	5 w wire wound
R20	150 k	1 w
R21	15 k	10 w Dividohm with 2 taps
R22	680 k	1/2 w
R23	82 k	1/2 w
R24, 25	100 k	1 w
R26	1 meg	1/2 w
R27	5.6 k	1/2 w
R28	270 k	1/2 w
R29	56 k	1/2 w
R30, 31, 32	220 k	1/2 w
R33	330 k	1/2 w
R34	68 k	1/2 w
R35	22 meg	1/2 w
R36	120 k	1/2 w
R37, 38	100 k	1 w
R39	10 k	1/2 w
R40	1 meg	1/2 w
R41	330 k	1/2 w
R42	390 k	1/2 w
R43	470 k	1 w
R44	68 k	1/2 w
R45	22 meg	1/2 w
R46	820 k	1/2 w
R47, 48	100 k	1 w
R49	1 meg	1/2 w
R50	10 k	1/2 w
R51	330 k	1/2 w
R52	Not used.	1/2 w
R53	470 k	1 w
R54	68 k	1/2 w
R55	Not used.	
R56	390 k	1/2 w

Condensers

C1, 2	75 pfd	600 VDC
C3	500 pfd	600 VDC
C4	27 pfd	600 VDC
C5	1 µfd	200 VDC Metalized
C6	100 pfd	600 VDC
C7	0.01 µfd	400 VDC Metalized
C8	5 µfd	400 VDC Metalized
C9	1000 pfd	600 VDC
C10, 11, 12	30 µfd	450 VDC Electrolytic
C13	500 pfd	600 VDC
C14	33 pfd	600 VDC
C15	0.1 µfd	400 VDC Metalized
C16, 17, 18, 19	100 pfd	600 VDC
C20	1000 pfd	600 VDC
C21	200 pfd	600 VDC
C22	300 pfd	600 VDC
C23	100 pfd	600 VDC
C24	1000 pfd	600 VDC
C25	200 pfd	600 VDC
C26	300 pfd	600 VDC

Tubes

V1	12AT7
V2, V3	12AX7
V4, V5	5V4G
V6	12AT7
V7	GC-10-D
V8	12AX7
V9	GC-10-B
V10	12AX7
V11	GC-10-B

Miscellaneous

T1	Transformer Stancor PC8408
T2	Transformer Stancor PC8402
D1, D2	Diodes 1N34
D3	Diode 1N39
S1	Push Switch (Switchcraft 4003NPSW)
S2	Phone Jack Mallory IA-2
S3	On-Off Switch SPST GC-1330
NE	Neon Lamp Assembly, Johnson Co. 147-1122
F	Buss HKL-X Fuze Holder, AGC-1 Fuze
L1	Choke 16 henry, Stancor C1003
L2	Choke, 10.5 henry, Stancor C1001

TABLE 1
VOLTAGE AND RESISTANCE MEASUREMENTS ON THE
SPINNING DISK RANDOM SELECTOR MODEL 1

Note: This equipment will normally operate with a supply voltage between 95 and 130 vac. Differences in tubes and components may in some cases limit this range.

The following data are for one set of tubes with a nominal input supply voltage. Thus variations can be expected between different equipments. In general these measurements can be used as a service guide.

A. C. VOLTAGES

Measured with a Triplett 630-NA

Measurement Point	Voltage	Comments
E line	111 VRMS	
V13 Between Pins 4 and 6	460 VRMS	
V14 Between Pins 4 and 6	670 VRMS	

D.C. SUPPLY VOLTAGES

Measures with a Triplett 630-NA

Measurement Point	Voltage	Comments
V14 Pin 8	+290 VDC	Relative to Ground
C28	+285 VDC	Relative to Ground
V13 Pin 8	+210 VDC	Measured Relative to the Positive Side of C-28
C30	+240 VDC	Relative to Ground
C29	+490 VDC	Relative to Ground
420 Volt BUS	+410 VDC	Relative to Ground
460 Volt BUS	+470 VDC	Relative to Ground

TABLE I (Continued)

D.C. Voltages

Measured with a 122 Megohm VTVM, HP-410B

Measurement Point	Q-Switch	Voltage	Comments
V1 Pin 1 Plate	--------	125 V	
Pin 2 Grid	--------	-31 V	
Pin 6 Plate	--------	118 V	
Pin 7 Grid	--------	-38 V	
R5, 6, 7 Junction	Count	134 V	
	Read	134± ≃10V	
V2 Pin 6 Plate	Count	80 V	
	Read	50, 120 V	
Pin 7 Grid	Count	17 V	
	Read	28, 11 V	
Pin 8 Cathode	Count	29 V	
	Read	29- ≃ 1 to 3 V	
V3 Pin 1 Plate	Count	87 V	
	Read	42 V	
Pin 2 Grid	Count	16 V	
	Read	16+ ≃6 V	
Pin 3,8 Cathode	Count	23 V	
	Read	23- ≃3 V	
Pin 6 Plate	Count	180 V	
	Read	240 V	
Pin 7 Grid	Count	10 V	
	Read	5 V	
R19, 20 Junction	Count	55 V	
	Read	55-≃5 to 10 V	
V4 Pin 6 Cathode	Count	2.5 V	
	Read	0 V	No Glow on "0".
	Read	30 V	Glow on "0".
V5 Pin 1 Plate	Count	220 V	
	Read	220+≃5 to 20 V	
Pin 2 Grid	Count	6.5 V	
	Read	6.5+ ≃1 V	
Pin 3,8 Cathode	Count	21 V	
	Read	21- ≃1 to 3 V	
Pin 6 Cathode	Count	76 V	
	Read	76- ≃10 V	
Pin 7 Grid	Count	17 V	
	Read	17+≃3 V	
V6 Pin 10 Cathode	Count	2.2 V	
	Read	25 V	Glow on "1"
	Read	0 V	No Glow on "1"
V15 Pin 1 Plate	Count	225 V	
	Read	225 V	Glow not on 9 of tens.
	Read	200 V	Glow on 9 of tens.
Pin 2 Grid	Count	2.2 V	
	Read	0 V	Glow not on 9 of tens.
	Read	25 V	Glow on 9 of tens.

TABLE I (Continued)

Measurement Point	Q-Switch	Voltage	Comments
V15 Pin 3 Cathode	Count	9.5 V	
	Read	8 V	Glow not on 9 of tens.
	Read	28 V	Glow on 9 of tens.

The Following Measurements Are Made With the Modulus Selectors Off.

V9 Pin 1 Plate	-----	240 V
Pin 2 Grid	-----	0 V
Pin 3,8 Cathode	-----	5 V
Pin 6 Plate	-----	20 V
Pin 7 Grid	-----	5 V
V11 Pin 1 Plate	-----	240 V
Pin 2 Grid	-----	0 V
Pin 3,8 Cathode	-----	19 V
Pin 6 Plate	-----	50 V
Pin 7 Grid	-----	19 V
V12 Pin 1 Plate	-----	240 V
Pin 2 Grid	-----	0 V
Pin 3 Cathode	-----	22 V

The Following Measurements Are Made With V10 Connected to a Cathode With a Glow, But Not Zero, and V9 Connected to a Cathode With No Glow.

V9 Pin 2 Grid	Read	0 V
Pin 3,8 Cathode	Read	7 V
Pin 6 Plate	Read	28 V
Pin 7 Grid	Read	7 V
V10 Pin 7 Grid	Read	24 V
Pin 3, 8 Cathode	Read	26 V
Pin 1 Plate	Read	28 V
Pin 2 Grid	Read	7 V

The Following Measurements Are Made With V9 Connected to "0" And V10 Connected to "0". This Is The Coincidence Condition.

V9 Pin 2 Grid	Read	20 V
Pin 3 Cathode	Read	22 V
Pin 6 Plate	Read	230 V
Pin 7 Grid	Read	15 V
V10 Pin 7 Grid	Read	25 V
Pin 3, 8 Cathode	Read	27 V
Pin 1 Plate	Read	230 V
Pin 2 Grid	Read	15 V

TABLE I (Continued)

Resistances

All resistances measured to ground with a Triplett 630-NA.
Note the AC power must be off.

Measurement Point	Resistance	Comments
V1 Pin 1	70 K	
Pin 2	1 Meg	
V2 Pin 1	88 K	
Pin 2	80 K	
Pin 3	15 K	
V3 Pin 1	120 K	
Pin 2	1 Meg	
Pin 3,8	10 K	
Pin 6	120 K	
Pin 7	80 K	
R19, 20 Junction	50 K	
V4 Pin 6	68 K	
V5 Pin 1	120 K	
Pin 2	750 K	
Pin 3, 8	10 K	
Pin 6	120 K	
Pin 7	1 Meg	
R87, 88 Junction	65 K	
R90, 89 Junction	330 K	S4, Hundreds Modulus, at 0.
V9 Pin 7	33 K	
V12 Pin 3	5 K	
Pin 1	120 K	
250 V BUS	20 K	

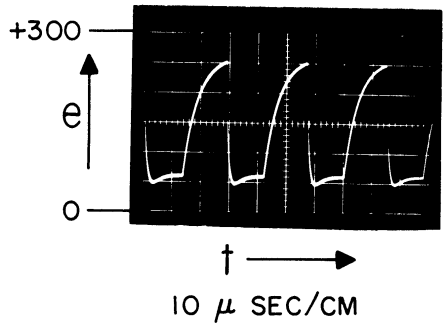
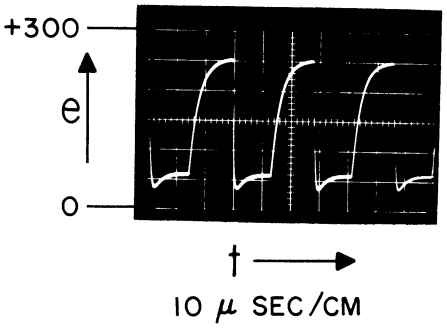
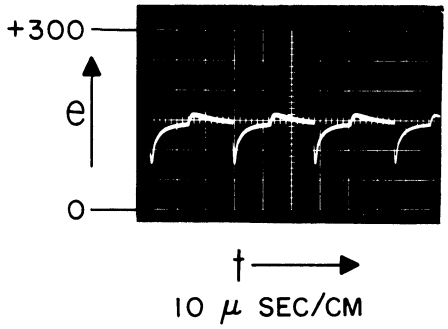
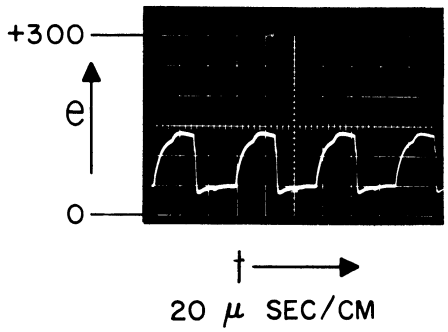
	MEASUREMENT POINT	TRIGGER SOURCE	POSITION OF Q-SW	NOTES
 (a)	V-1 PIN 6	EXT. V-1 PIN 6 NEGATIVE SLOPE	ON	
 (b)	V-1 PIN 6	EXT. V-1 PIN 6 NEGATIVE SLOPE	OFF	
 (c)	JUNCTION OF R_5, R_6, R_7	EXT. V-1 PIN 6 NEGATIVE SLOPE	ON	
 (d)	V-2 PIN 6	EXT. V-1 PIN 6 NEGATIVE SLOPE	ON	THIS WAVEFORM MAY BE SHIFTED BY ONE-HALF CYCLE.

TABLE 2

WAVEFORMS FOR THE CIRCUIT OF FIG. 7

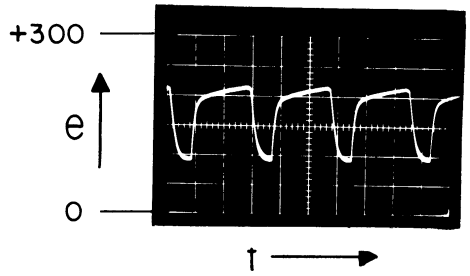
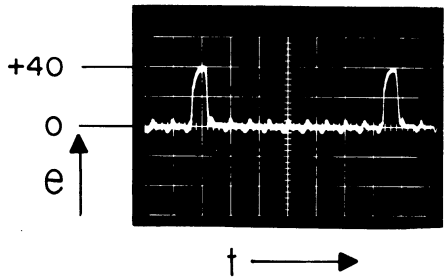
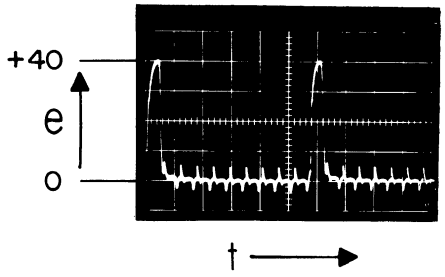
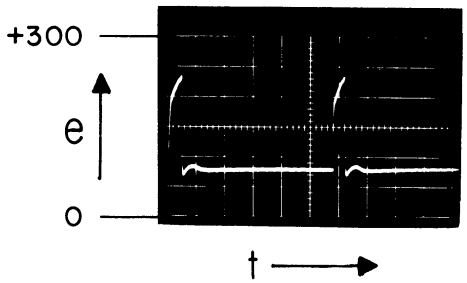
	MEASUREMENT POINT	TRIGGER SOURCE	POSITION OF Q-SW	NOTES
 (e) 20 μ SEC/CM	V-3 PIN 6	EXT. V-2 PIN 1 NEGATIVE SLOPE	ON	
 (f) BETWEEN 50 AND 100 μ SEC/CM	V-4 PIN 6	EXT. V-2 PIN 1 NEGATIVE SLOPE	ON	THE SWEEP RATE VERNIER MUST BE ADJUSTED TO STOP THE HORIZONTAL DRIFT OF THE WAVEFORM. MODULUS SELECTOR OFF
 (g) 100 μ SEC/CM	V-4 PIN 6	INT. POSITIVE SLOPE	ON	MODULUS SELECTOR OFF
 (h) 100 μ SEC/CM	V-5 PIN 6	EXT. V-4 PIN 6 POSITIVE SLOPE	ON	MODULUS SELECTOR OFF

TABLE 2 (CONT.)

WAVEFORMS FOR THE CIRCUIT OF FIG. 7

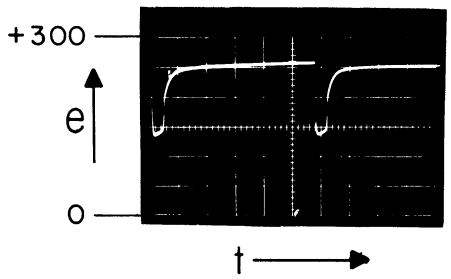
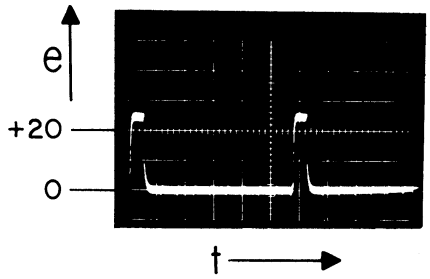
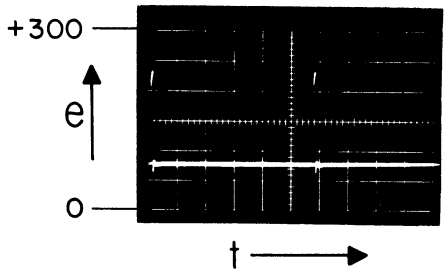
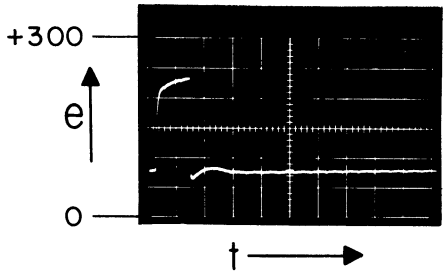
	MEASUREMENT POINT	TRIGGER SOURCE	POSITION OF Q-SW	NOTES
 (i)	V-5 PIN 1	EXT. V-4 PIN 6 POSITIVE SLOPE	ON	MODULUS SELECTOR OFF
 (j)	V-6 PIN 1	INT. POSITIVE SLOPE	ON	MODULUS SELECTOR OFF
 (k)	V-7 PIN 6	EXT. V-6 PIN 2 NEGATIVE SLOPE	ON	MODULUS SELECTOR OFF
 (l)	V-7 PIN 6	EXT. V-6 PIN 2 NEGATIVE SLOPE	ON	MODULUS SELECTOR OFF

TABLE 2 (CONT.)

WAVEFORMS FOR THE CIRCUIT OF FIG. 7

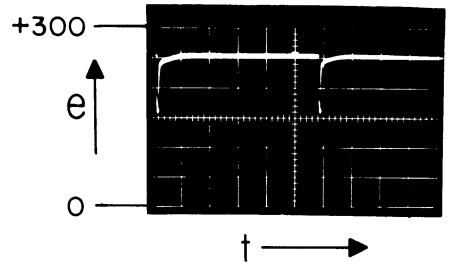
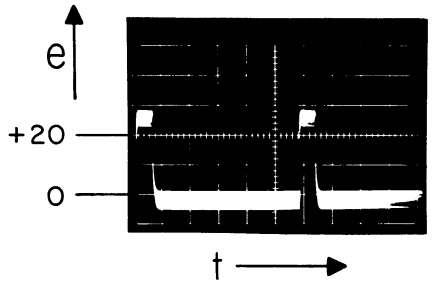
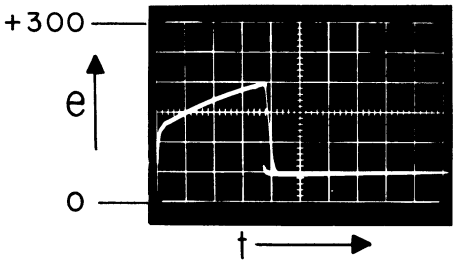
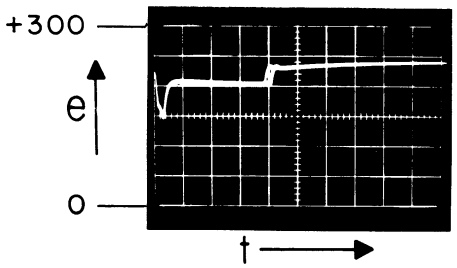
	MEASUREMENT POINT	TRIGGER SOURCE	POSITION OF Q-SW	NOTES
 (m) 1 MILLISEC/CM	V-7 PIN 1	EXT. V-6 PIN 2 NEGATIVE SLOPE	ON	MODULUS SELECTOR OFF
 (n) 10 MILLISEC/CM	V-8 PIN 1	INT. POSITIVE SLOPE	ON	MODULUS SELECTOR OFF
 (o) 20 μ SEC/CM	V-11 PIN 6	INT. POSITIVE SLOPE	ON	MODULUS SELECTOR HUNDREDS 0 TENS 6
 (p) 20 μ SEC/CM	V-11 PIN 1	INT. NEGATIVE SLOPE	ON	MODULUS SELECTOR HUNDREDS 0 TENS 6

TABLE 2 (CONT.)

WAVEFORMS FOR THE CIRCUIT OF FIG. 7

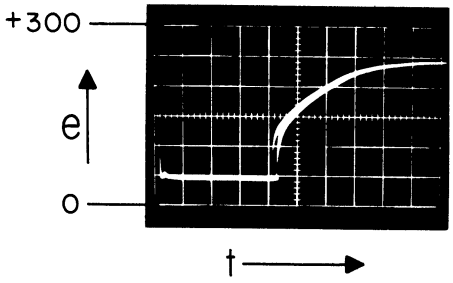
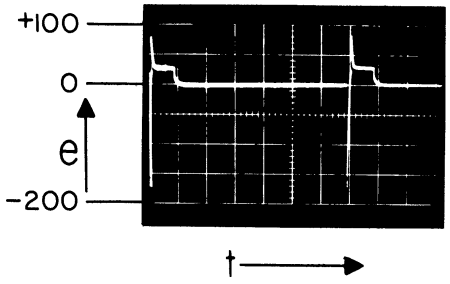
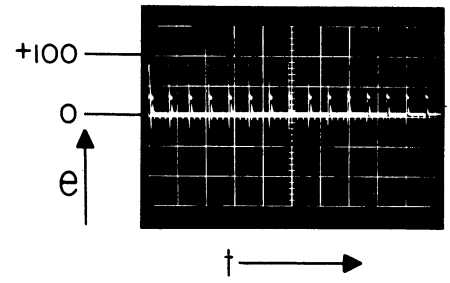
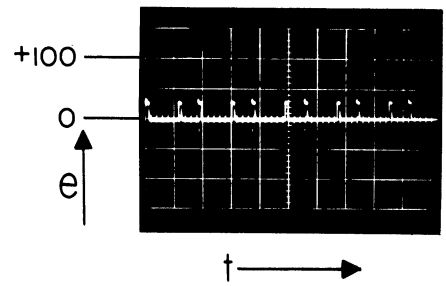
	MEASUREMENT POINT	TRIGGER SOURCE	POSITION OF Q-SW	NOTES
 (q)	V-12 PIN 1	INT. NEGATIVE SLOPE	ON	MODULUS SELECTOR HUNDREDS 0 TENS 6
 (r)	V-6 PIN 1	INT. NEGATIVE SLOPE	ON	MODULUS SELECTOR HUNDREDS 0 TENS 6
 (s)	V-6 JUNCTION BETWEEN D-2 & R-43	EXT. POSITIVE SLOPE JUNCTION BETWEEN D-3 & R-62	ON	MODULUS SELECTOR HUNDREDS 0 TENS 6
 (t)	V-6 JUNCTION BETWEEN D-2 & R-43	EXT. POSITIVE SLOPE JUNCTION BETWEEN D-3 & R-62	ON	MODULUS SELECTOR HUNDREDS 0 TENS 6

TABLE 2 (CONT.)

WAVEFORMS FOR THE CIRCUIT OF FIG. 7.

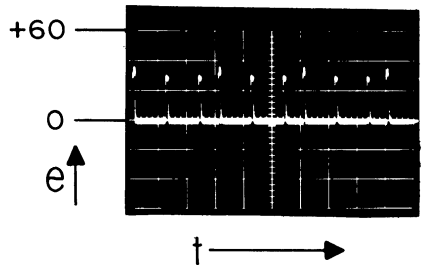
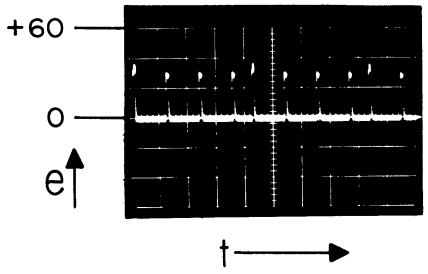
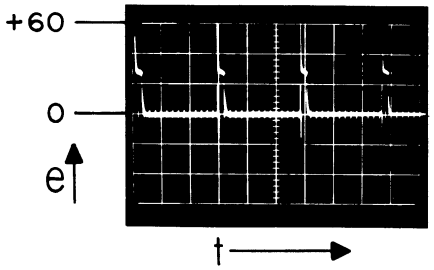
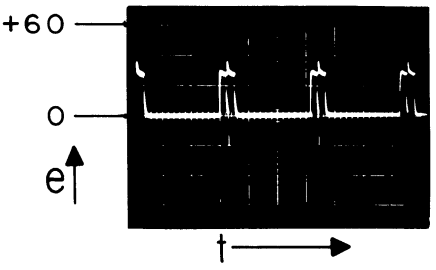
	MEASUREMENT POINT	TRIGGER SOURCE	POSITION OF Q-SW	NOTES
 (u) 5 MILLISEC/CM	V-6 JUNCTION BETWEEN D-2 & R-43	EXT. POSITIVE SLOPE D-3 & R-62	ON	MODULUS SELECTOR HUNDREDS 2 TENS 6
 (v) 5 MILLISEC/CM	SAME AS (u)	SAME AS (u)	ON	MODULUS SELECTOR HUNDREDS 3 TENS 6
 (w) 2 MILLISEC/CM	SAME AS (u)	SAME AS (u)	ON	MODULUS SELECTOR HUNDREDS 1 TENS 0
 (x) 2 MILLISEC/CM	SAME AS (u)	SAME AS (u)	ON	MODULUS SELECTOR HUNDREDS 1 TENS 1

TABLE 2 (CONT.)

WAVEFORMS FOR THE CIRCUIT OF FIG. 7

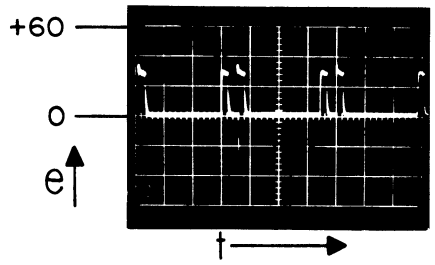
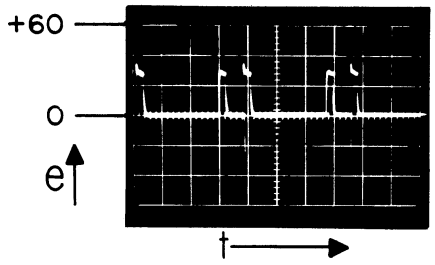
	MEASUREMENT POINT	TRIGGER SOURCE	POSITION OF Q-SW	NOTES
 (y) 2 MILLISEC/CM	SAME AS (u)	SAME AS (u)	ON	MODULUS SELECTOR HUNDREDS 1 TENS 2
 (z) 2 MILLISEC/CM	SAME AS (u)	SAME AS (u)	ON	MODULUS SELECTOR HUNDREDS 1 TENS 3

TABLE 2 (CONT.)

WAVEFORMS FOR THE CIRCUIT OF FIG. 7

Table 3

Components for Type "C", Model 1, Serial 1

Resistors

Quantity	Resistance	Wattage	
2	2.2 k	1/2 w	
2	5.6 k	1/2 w	
4	10 k	1/2 w	
1	12 k	1/2 w	
1	33 k	1/2 w	
2	47 k	2 w	
5	47 k	1 w	
2	56 k	2 w	
1	56 k	1/2 w	
23	68 k	1/2 w	
1	82 k	1/2 w	
11	100 k	1 w	
7	100 k	1/2 w	
1	150 k	1 w	
3	220 k	1/2 w	
3	270 k	1/2 w	
3	330 k	1/2 w	
2	390 k	1/2 w	
4	470 k	1/2 w	
2	680 k	1/2 w	
2	820 k	1/2 w	
8	1 m	1/2 w	
2	3.3 m	1/2 w	
2	22 m	1/2 w	
1	1 k	10 w	wire wound
1	15 k	25 w	dividohm with 2 taps

Table 3 (Continued)

Condensers

Quantity	Capacitance	Rating	
1	15 pfd	600 VDC	Ceramic
4	33 pfd	600 VDC	"
2	47 pfd	600 VDC	"
5	100 pfd	600 VDC	"
3	200 pfd	600 VDC	"
2	300 pfd	600 VDC	"
4	500 pfd	600 VDC	"
2	1000 pfd	600 VDC	"
1	1500 pfd	600 VDC	"
1	5000 pfd	600 VDC	"
2	1 µfd	200 VDC	Metalized
3	30 µfd	450 VDC	Electrolytic

Tubes

Quantity	Type
2	5V4 GA
7	12AT7
2	12AX7
1	5963
2	GS-10-C
1	GC-10-D

Table 4

Components for Model 2, Serial 1

Resistors

Quantity	Resistance	Wattage
1	5.6 k	1/2 w
3	10 k	1/2 w
3	47 k	1 w
1	56 k	1/2 w
3	68 k	1/2 w
1	82 k	1/2 w
2	100 k	1/2 w
9	100 k	1 w
1	150 k	1 w
3	220 k	1/2 w
1	270 k	1/2 w
2	330 k	1/2 w
1	330 k	1 w
2	390 k	1/2 w
2	470 k	1/2 w
1	560 k	1/2 w
1	680 k	1/2 w
2	820 k	1/2 w
6	1 meg	1/2 w
2	2.2 meg	1/2 w
1	2.7 meg	1/2 w
1	5 meg	2 w AB Pot.
2	22 meg	1/2 w
1	1 k	5 w wire wound
1	15 k (with 2 taps)	10 w Dividohm

Condensers

Quantity	Capacitance	Rating	
1	27 pfd	600 VDC	ceramic
1	33 pfd	600 VDC	ceramic
2	75 pfd	600 VDC	ceramic
6	100 pfd	600 VDC	ceramic
2	200 pfd	600 VDC	ceramic
2	300 pfd	600 VDC	ceramic
2	500 pfd	600 VDC	ceramic
3	1000 pfd	600 VDC	ceramic
1	0.01 µfd	400 VDC	metalized
1	0.1 µfd	400 VDC	metalized
1	1.0 µfd	200 VDC	metalized
1	5 µfd	400 VDC	metalized
3	30 µfd	450 VDC	electrolytic

Tubes

Quantity	Type
2	5V4 GA
2	12AT7
4	12AX7
2	GC-10-B
1	GC-10-D

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