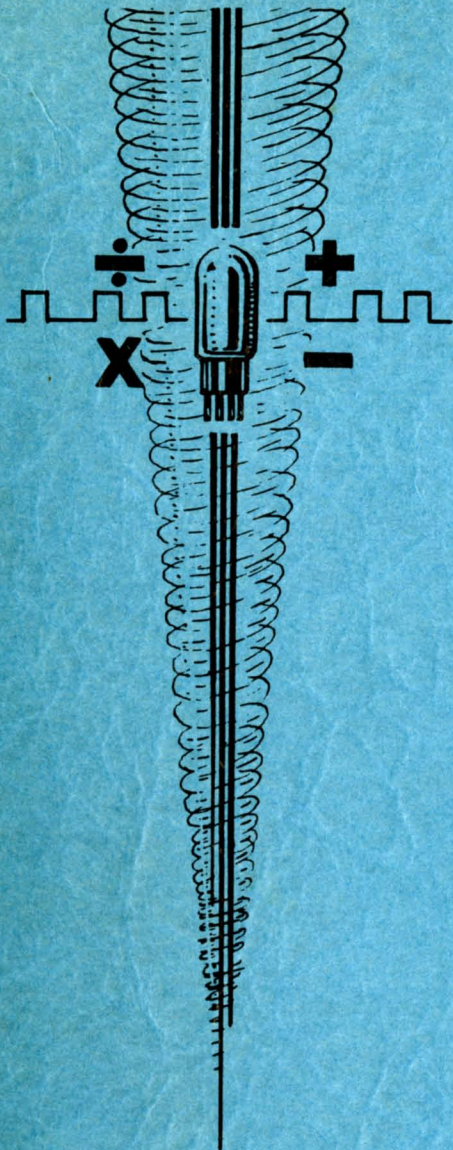


Haley
Presentation

PROJECT WHIRLWIND

Contract N5ori60
Project NR-720-003



R-134

THE FIVE-DIGIT MULTIPLIER

DECEMBER 3, 1948

VOLUME 2

**SERVOMECHANISMS LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY**

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25



PROJECT WHIRLWIND

Report E-134

FIVE-DIGIT MULTIPLIER

Volume 2 of 2 Volumes

Submitted to the

OFFICE OF NAVAL RESEARCH
Under Contract N5or160
Project NR-720-003

Report by N. H. Taylor

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SERVOMECHANISMS LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge 39, Massachusetts

Project DIC 6345

December 3, 1948

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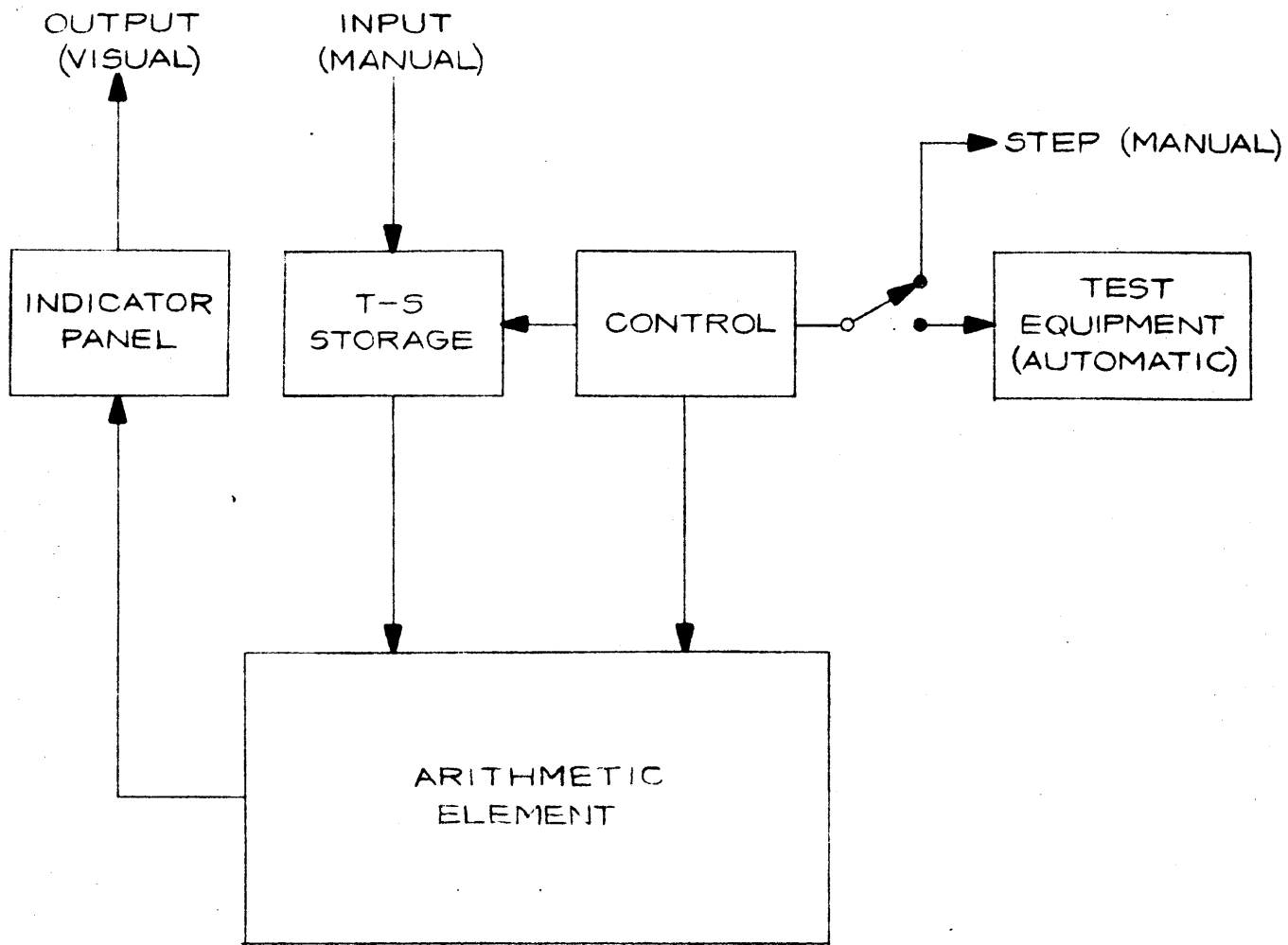


FIG. 1
FUNCTIONAL RELATIONSHIP OF UNITS
IN FIVE-DIGIT MULTIPLIER

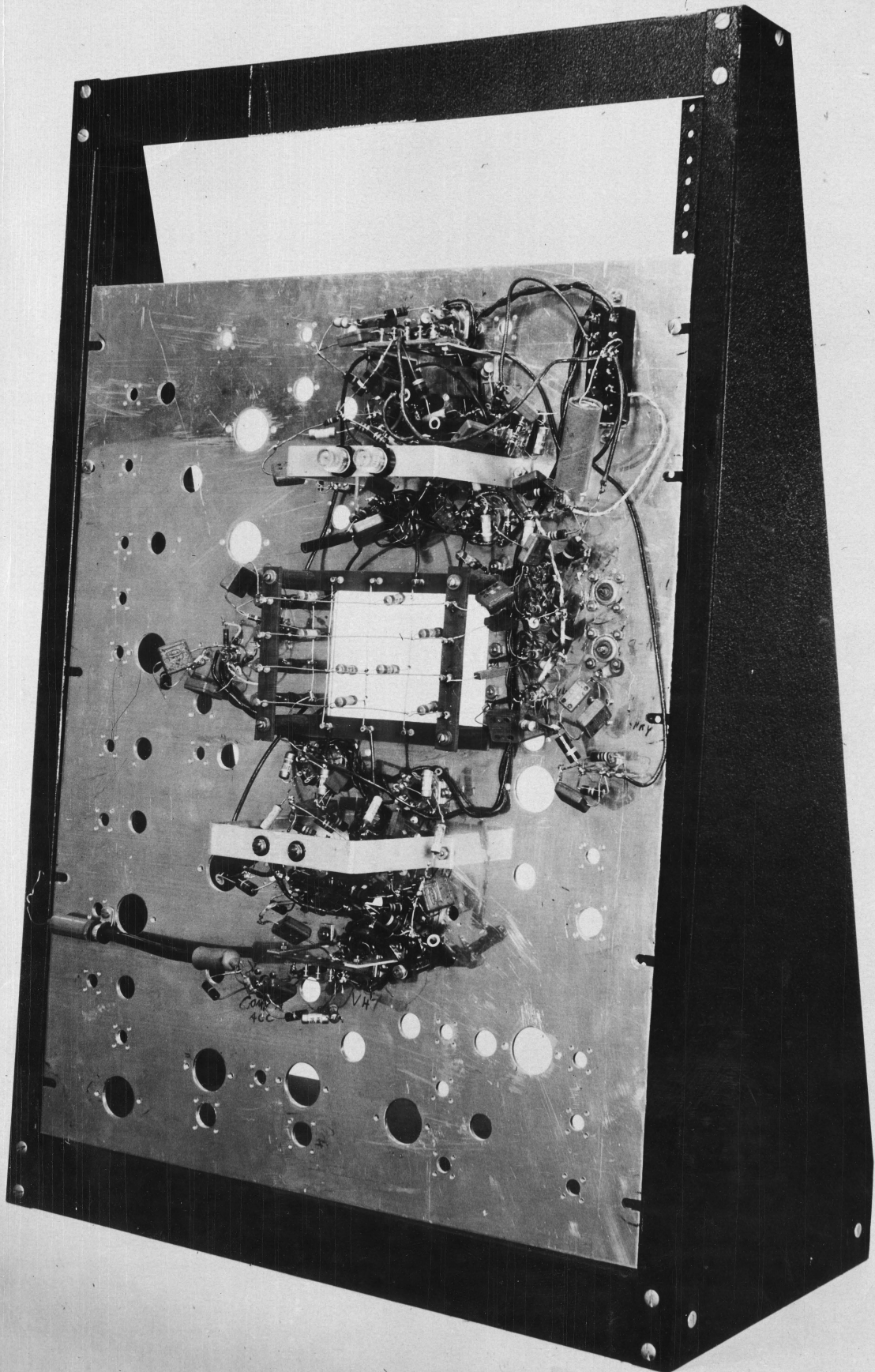


FIG. 2
SHIFT-AND-CARRY BREADBOARD

FB 245

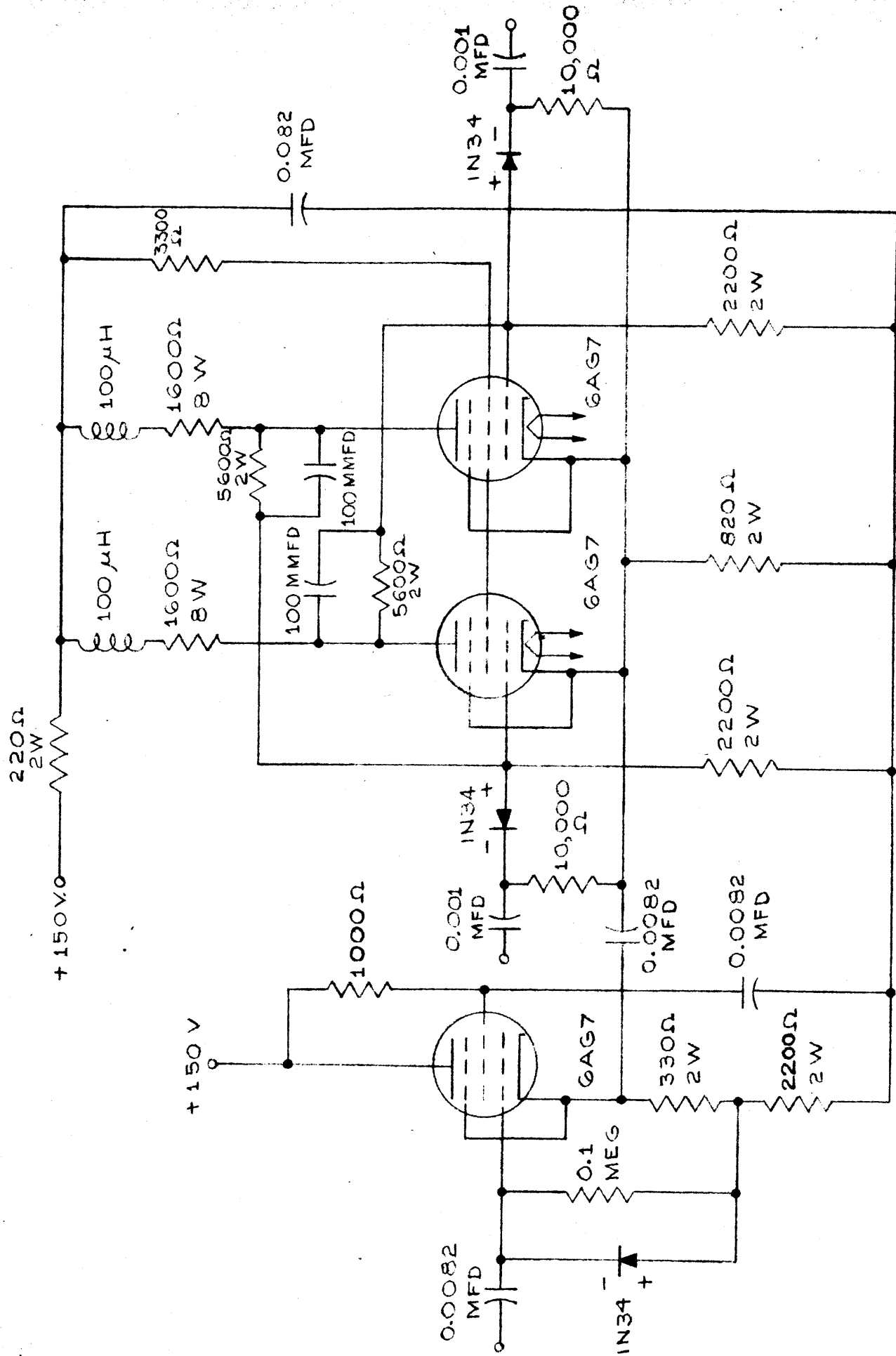
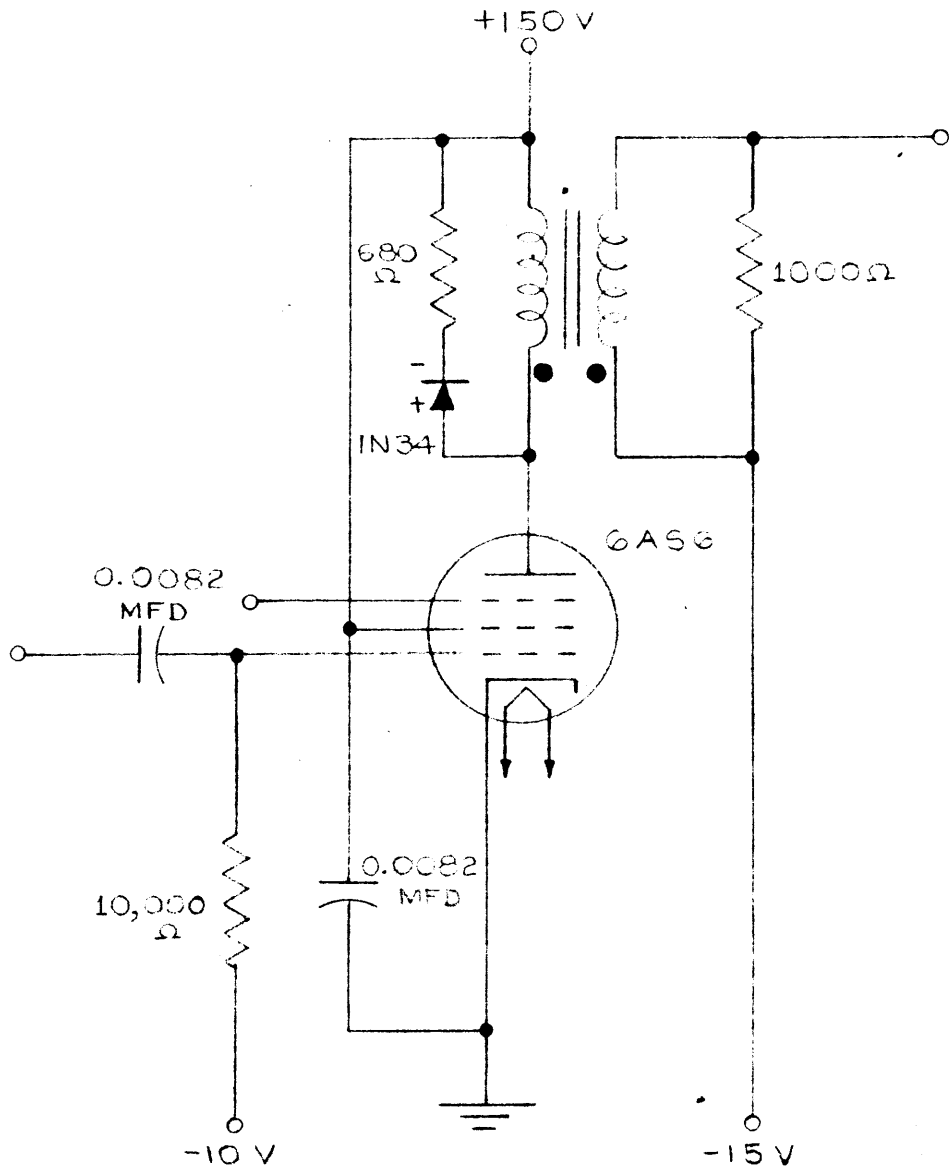


FIG.

33 CIRCUIT SCHEMATIC OF FLIP-FLOP AND TRIGGER TUBE USED IN THE FIVE-DIGIT MULTIPLIER

A-3240 USED IN 6345 REPORTS: R-139 R-134



GATE CIRCUIT USED IN THE FIVE-DIGIT MULTIPLIER

A-20A USED IN G345 REPORT R-12

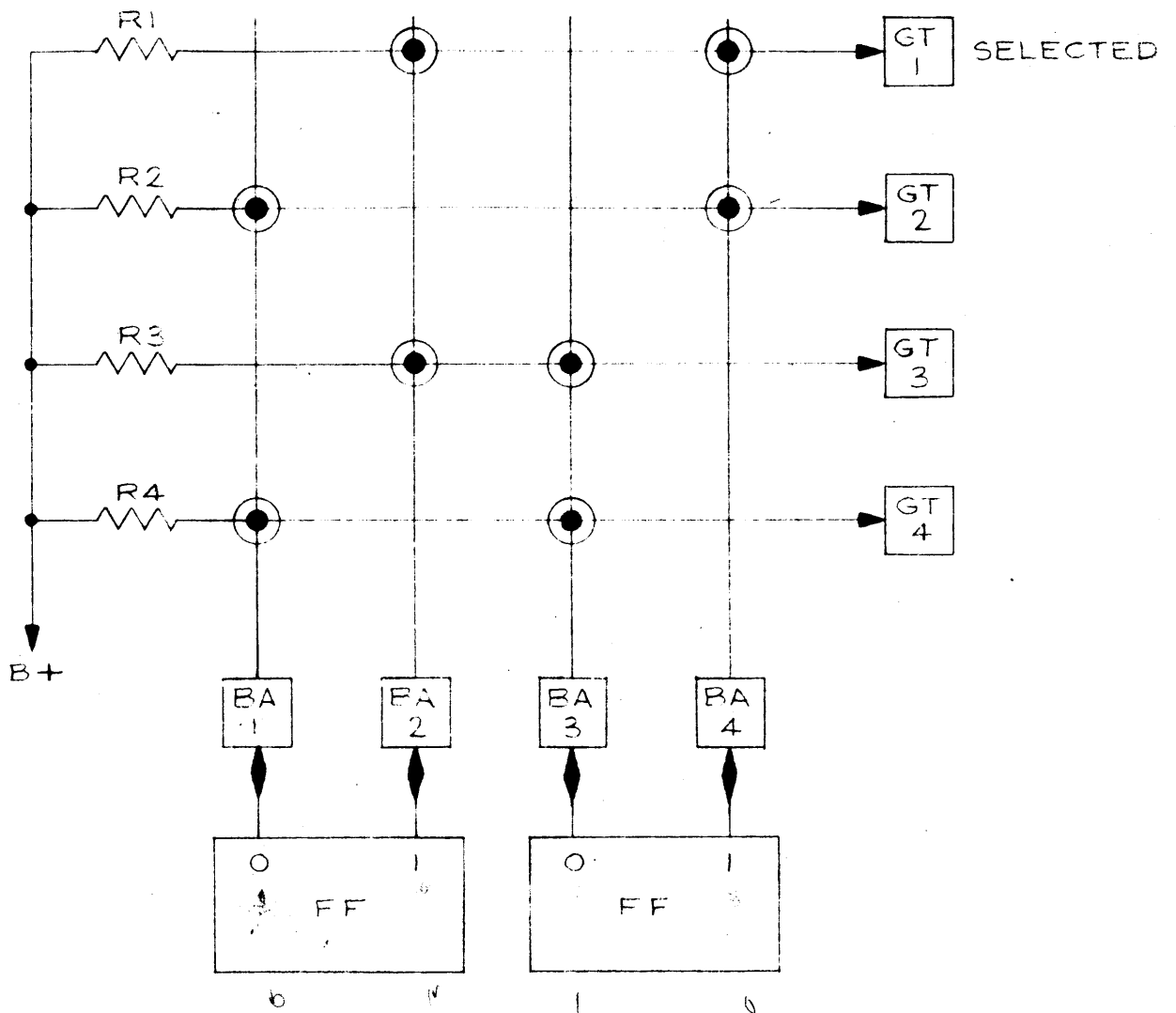
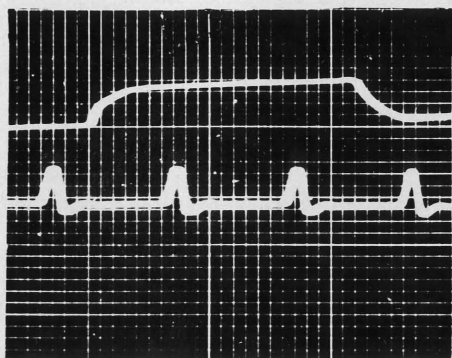


FIGURE 5
FOUR-POSITION MATRIX
SWITCH



FF OUTPUT

2-MEGACYCLE CLOCK
PULSES

SCALE:

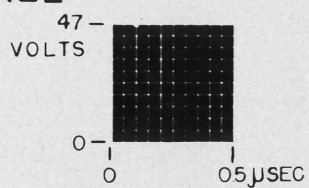


FIGURE 6

TIMING OF 2-MEGACYCLE PULSES
ON FF WAVEFORM

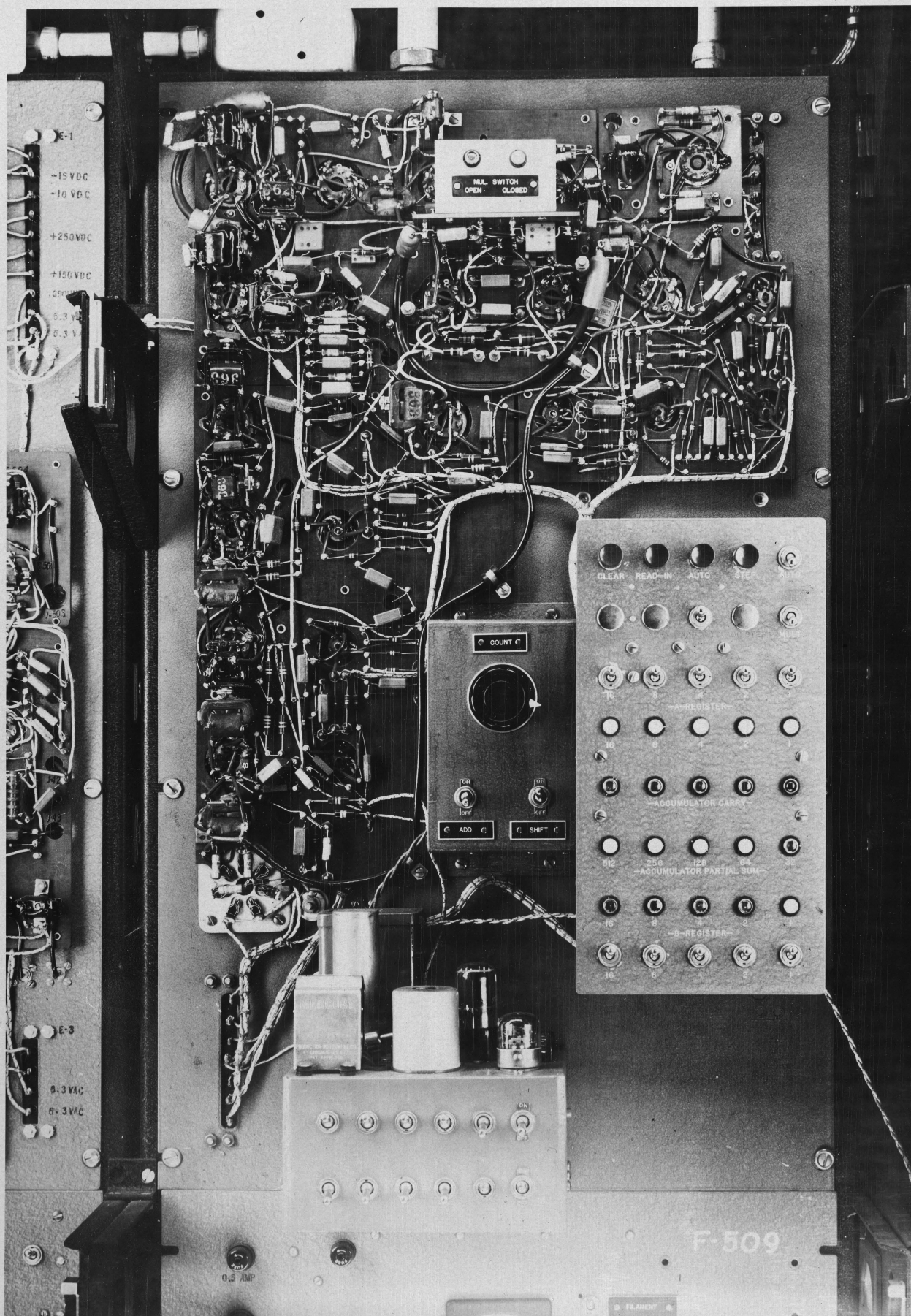
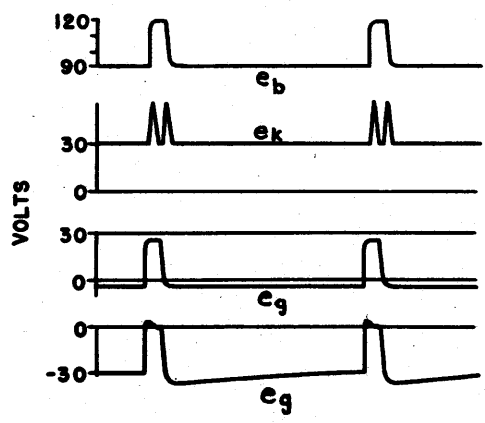
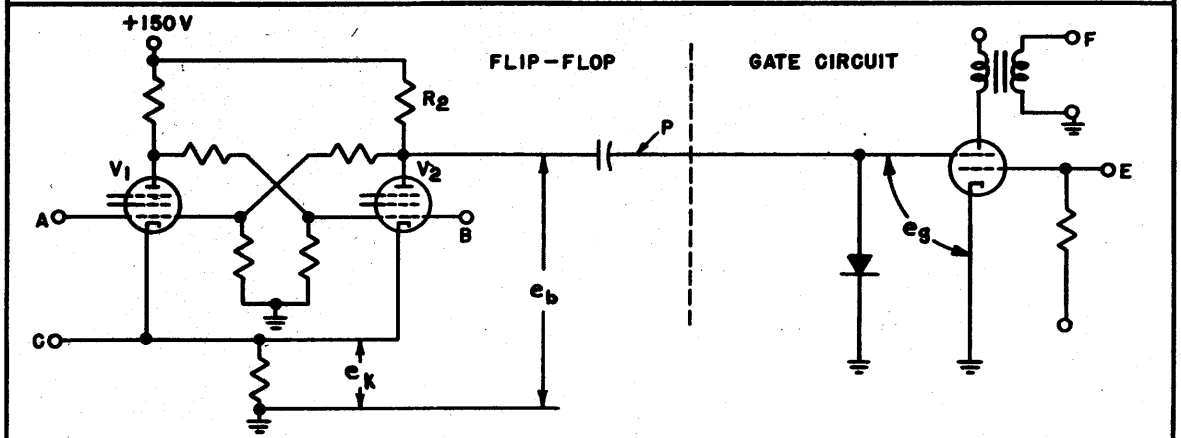
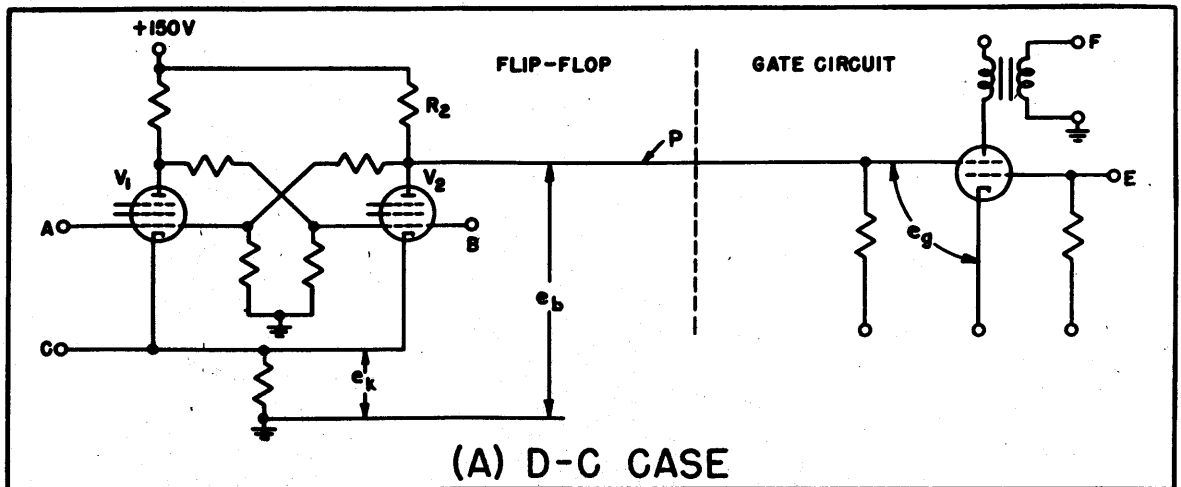


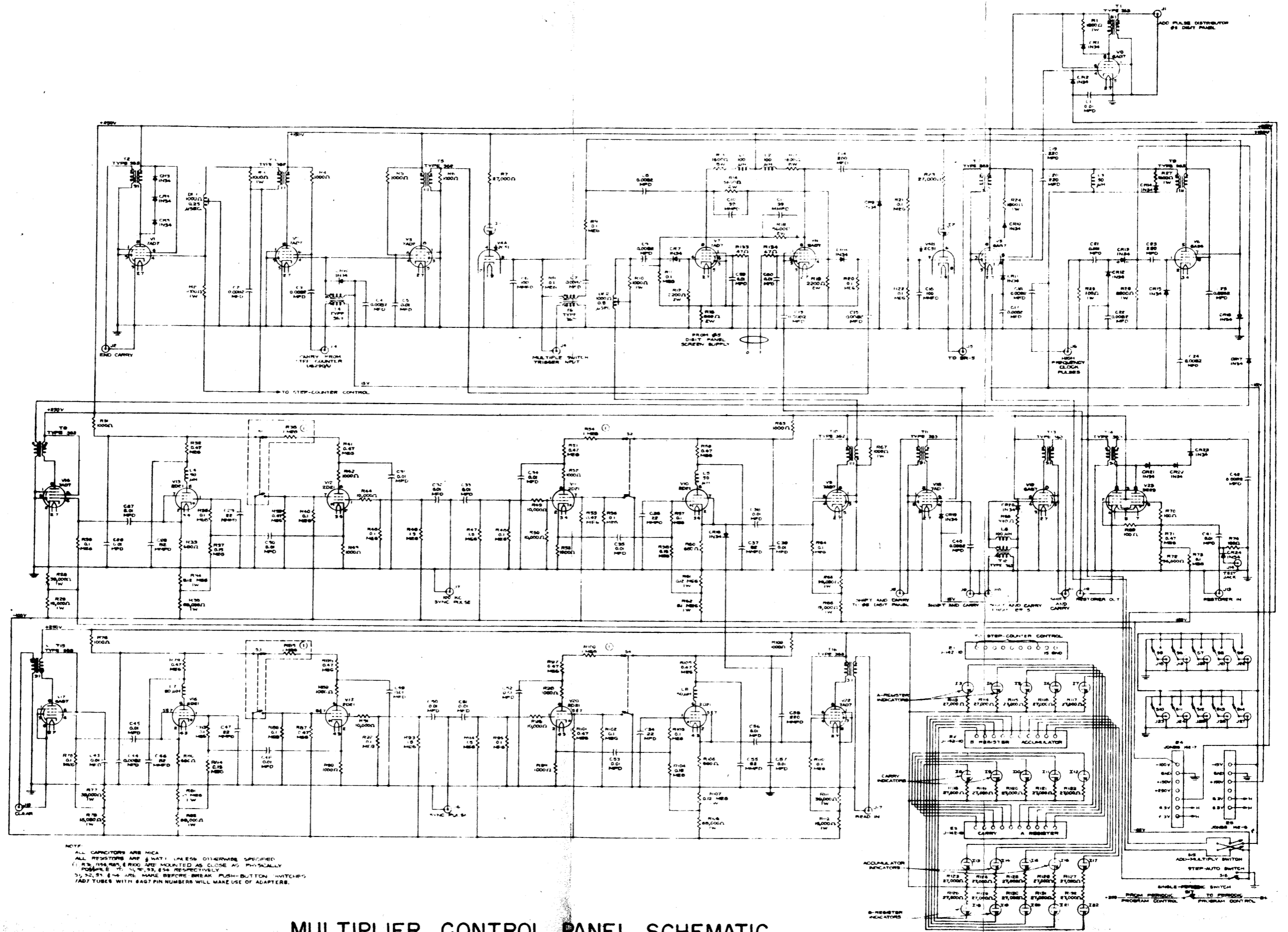
FIG. 7
CONTROL PANEL



- (1) VOLTAGE SWING AT PLATE OF FF.
- (2) RESTORER PULSES AT CATHODE OF FF.
- (3) VOLTAGE SWING AT GRID OF GATE TUBE (RESISTOR USED).
- (4) VOLTAGE SWING AT GRID OF GATE TUBE (CRYSTAL USED).

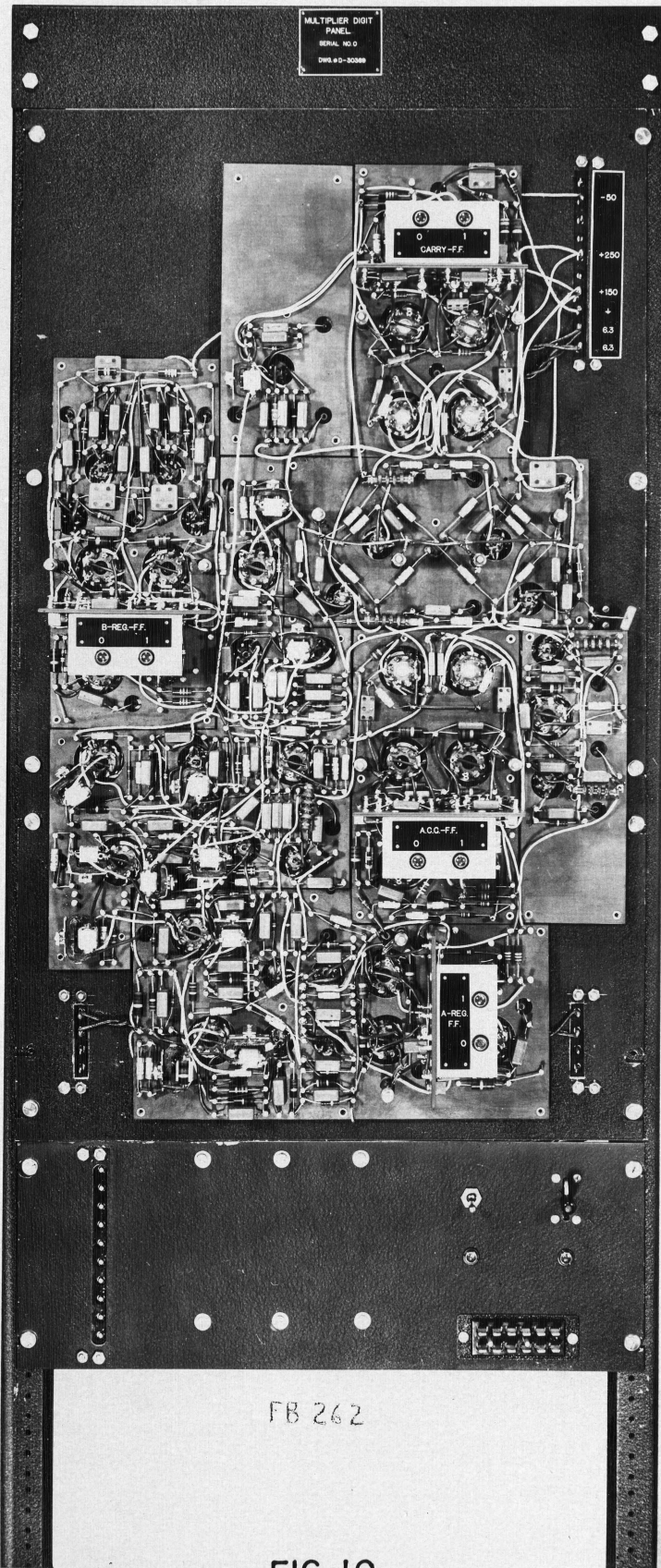
(B) A-C CASE

**FIGURE 8
COUPLING METHODS**



MULTIPLIER CONTROL PANEL SCHEMATIC

FIG. 9



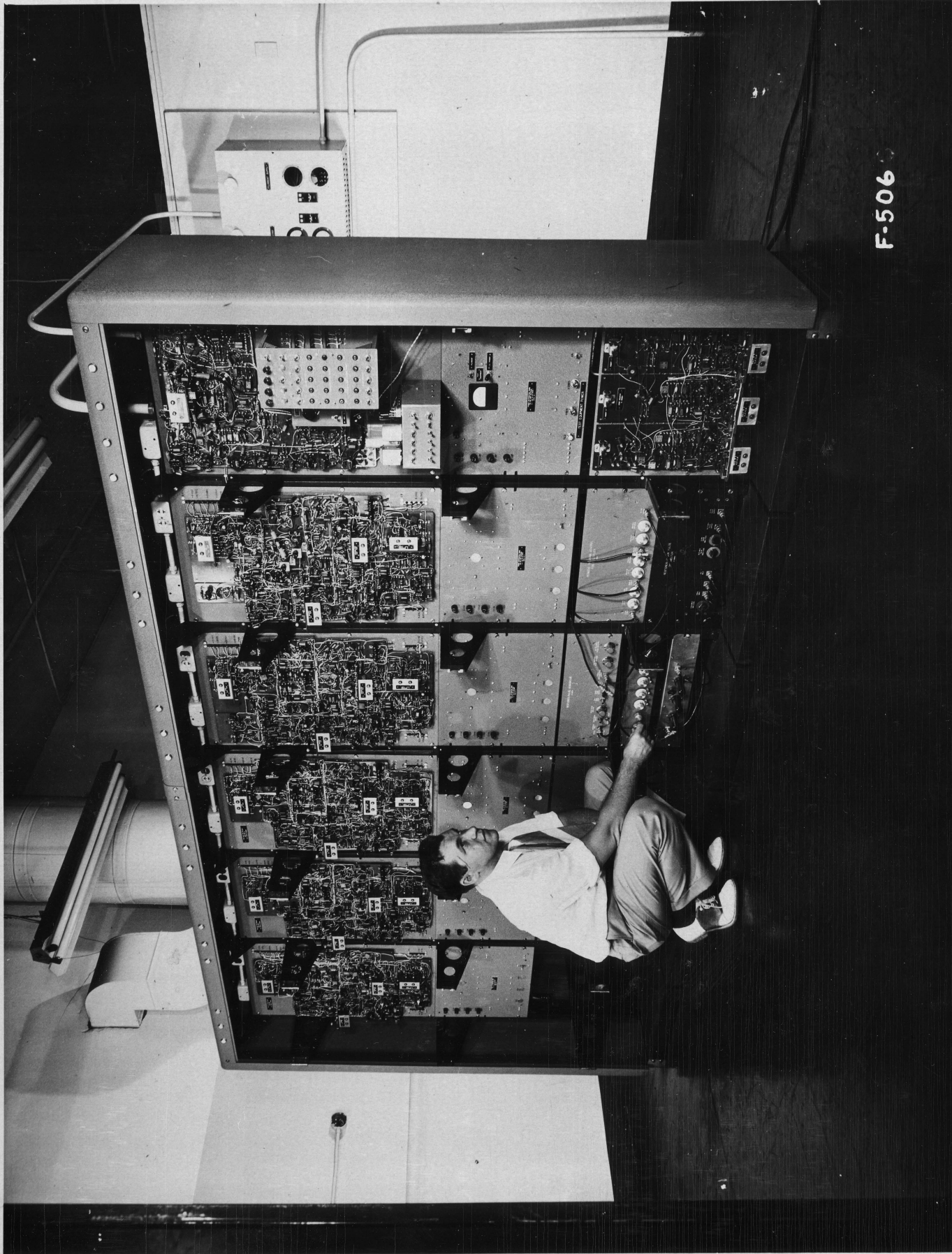
FB 262

FIG. 10
SINGLE DIGIT PROTOTYPE



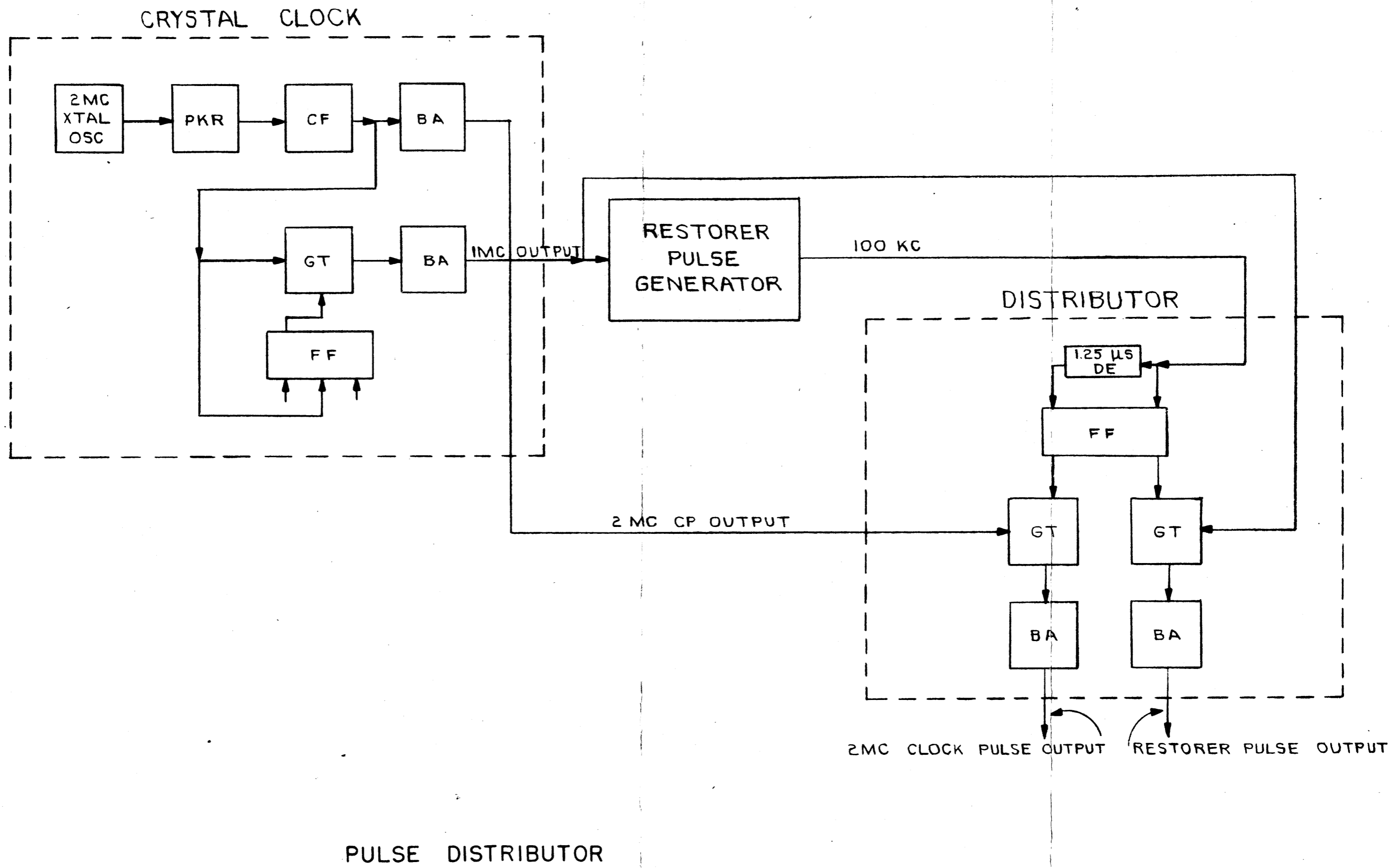
F-508

FIG. 11
COMPLETE ASSEMBLY 5-DIGIT MULTIPLIER



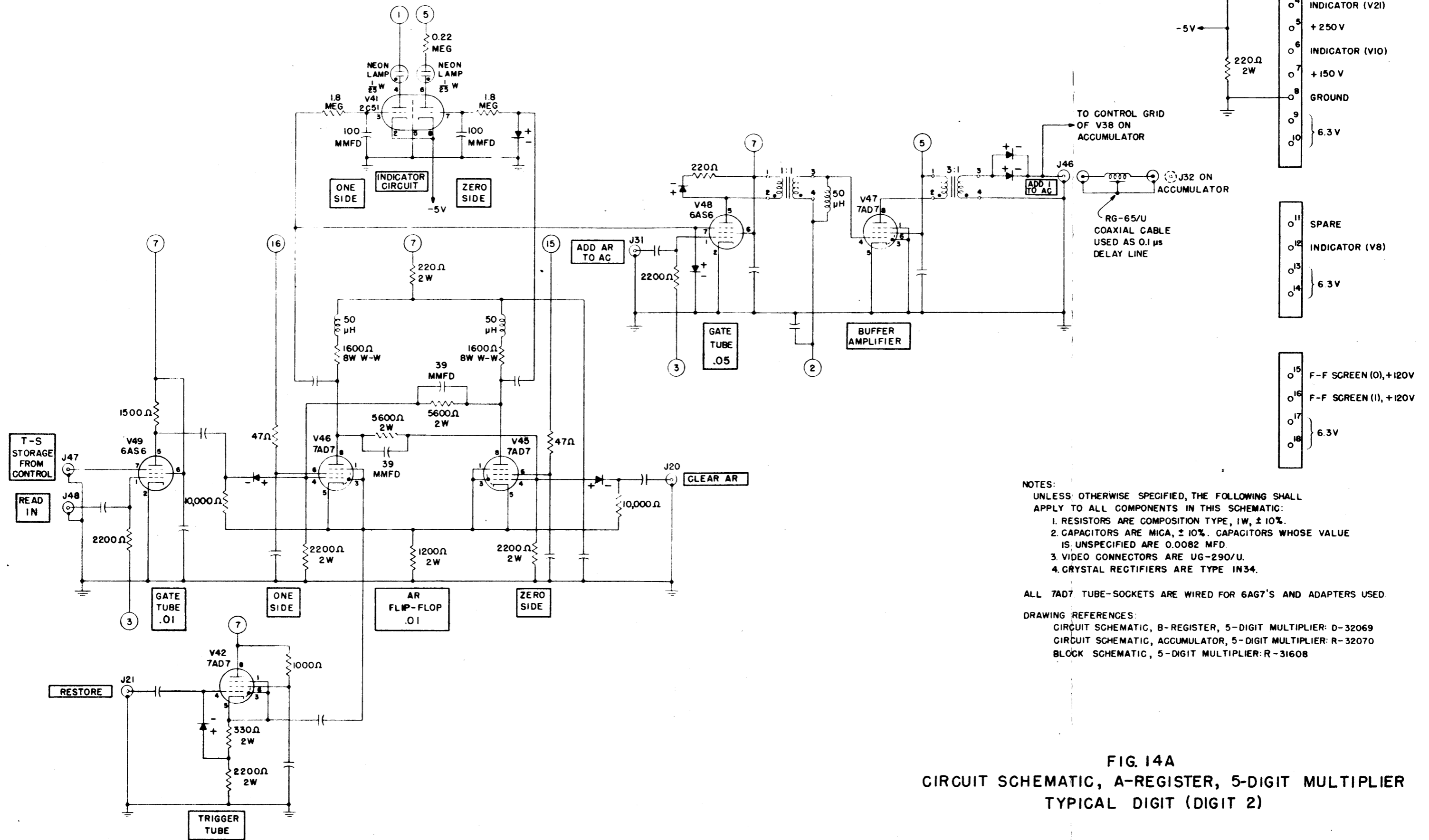
F-506

FIG. 12
COMPLETE ASSEMBLY 5-DIGIT MULTIPLIER



PULSE DISTRIBUTOR

FIG. 13

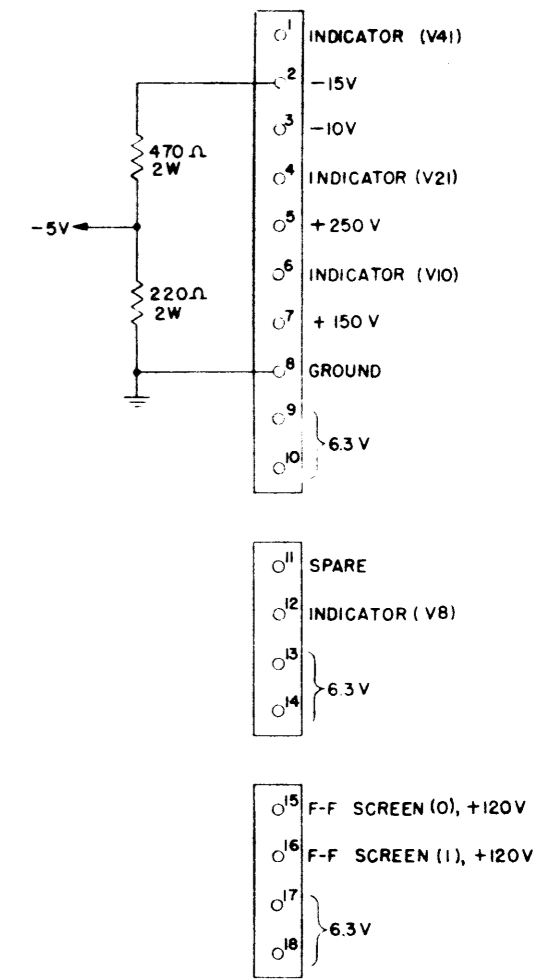
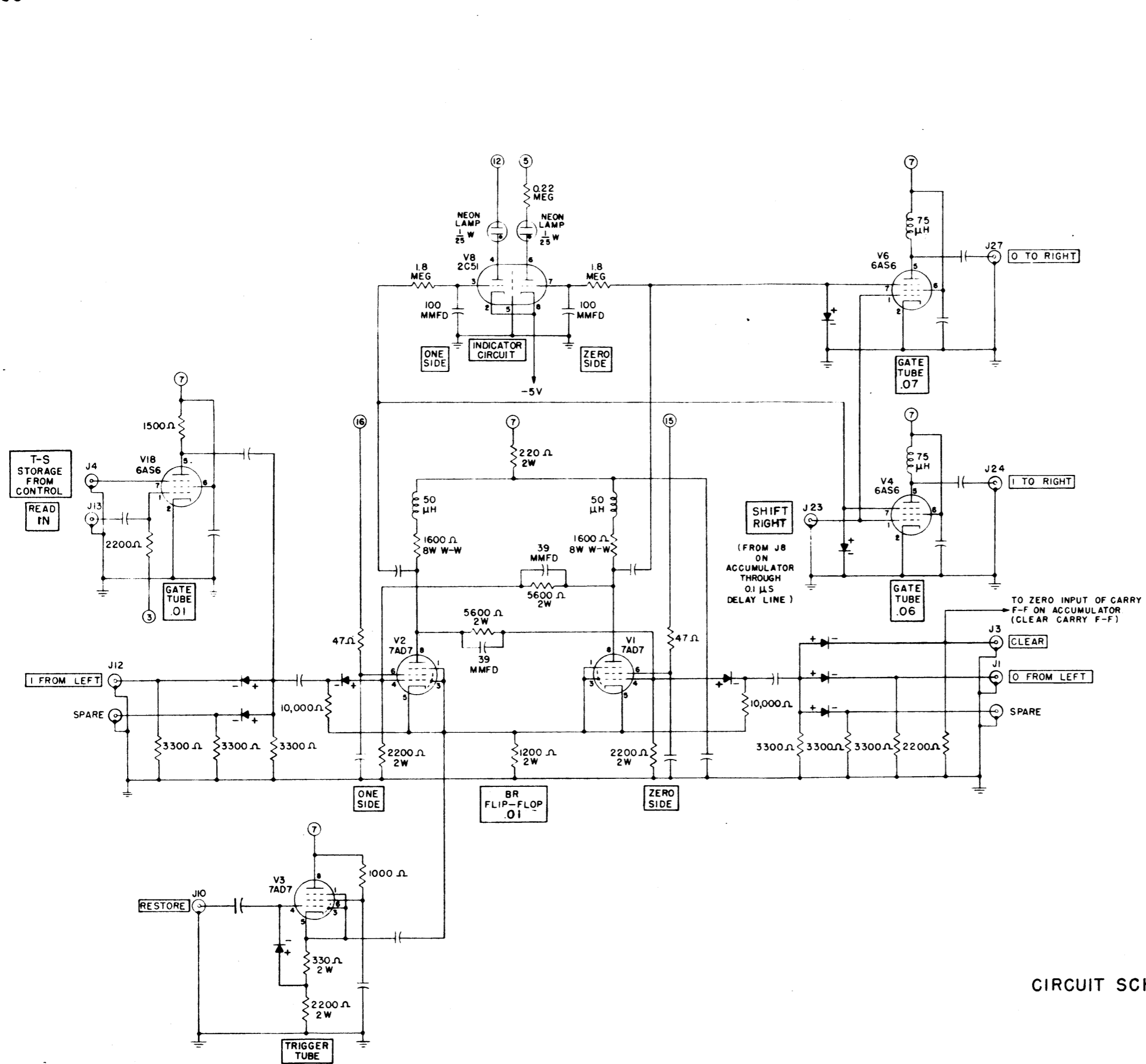


NOTES:
 UNLESS OTHERWISE SPECIFIED, THE FOLLOWING SHALL APPLY TO ALL COMPONENTS IN THIS SCHEMATIC:
 1. RESISTORS ARE COMPOSITION TYPE, 1W, ± 10%.
 2. CAPACITORS ARE MICA, ± 10%. CAPACITORS WHOSE VALUE IS UNSPECIFIED ARE 0.0082 MFD.
 3. VIDEO CONNECTORS ARE UG-290/U.
 4. CRYSTAL RECTIFIERS ARE TYPE IN34.

ALL 7AD7 TUBE-SOCKETS ARE WIRED FOR 6AG7'S AND ADAPTERS USED.

DRAWING REFERENCES:
 CIRCUIT SCHEMATIC, B-REGISTER, 5-DIGIT MULTIPLIER: D-32069
 CIRCUIT SCHEMATIC, ACCUMULATOR, 5-DIGIT MULTIPLIER: R-32070
 BLOCK SCHEMATIC, 5-DIGIT MULTIPLIER: R-31608

FIG. 14A
 CIRCUIT SCHEMATIC, A-REGISTER, 5-DIGIT MULTIPLIER
 TYPICAL DIGIT (DIGIT 2)



NOTES:

UNLESS OTHERWISE SPECIFIED, THE FOLLOWING SHALL APPLY TO ALL COMPONENTS IN THIS SCHEMATIC:

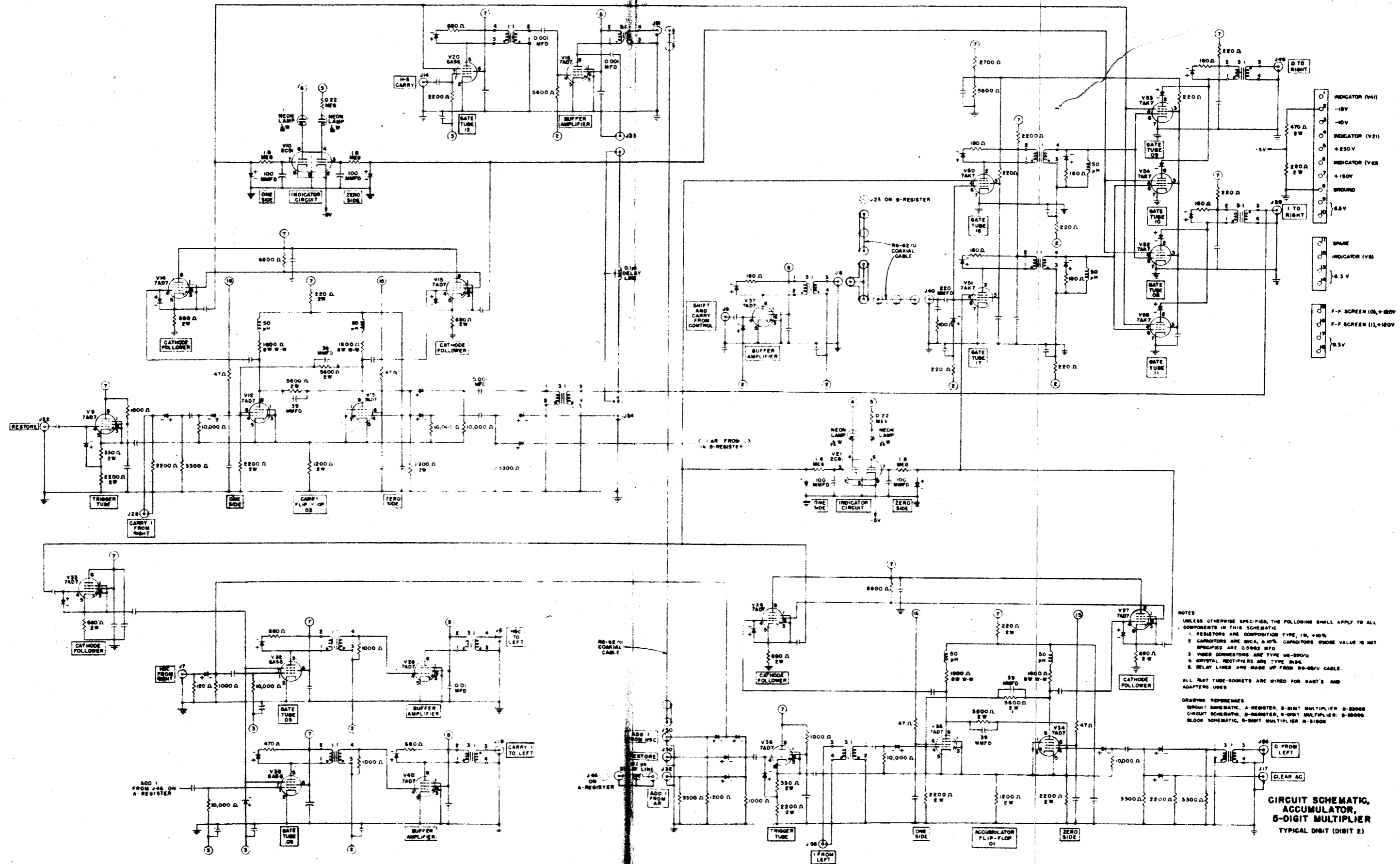
1. RESISTORS ARE COMPOSITION TYPE, 1W, $\pm 10\%$.
2. CAPACITORS ARE MICA, $\pm 10\%$. CAPACITORS WHOSE VALUE IS NOT SPECIFIED ARE 0.0082 MFD.
3. VIDEO CONNECTORS ARE TYPE UG-290/U.
4. CRYSTAL RECTIFIERS ARE TYPE IN34.

ALL 7AD7 TUBE-SOCKETS ARE WIRED FOR 6AG7'S AND ADAPTERS USED.

DRAWING REFERENCES:

CIRCUIT SCHEMATIC, A-REGISTER, 5-DIGIT MULTIPLIER: D-32068
 CIRCUIT SCHEMATIC, ACCUMULATOR, 5 DIGIT MULTIPLIER: R-32070
 BLOCK SCHEMATIC, 5-DIGIT MULTIPLIER: R-31608.

FIG. 14B
 CIRCUIT SCHEMATIC, B-REGISTER, 5-DIGIT MULTIPLIER
 TYPICAL DIGIT (DIGIT 2)

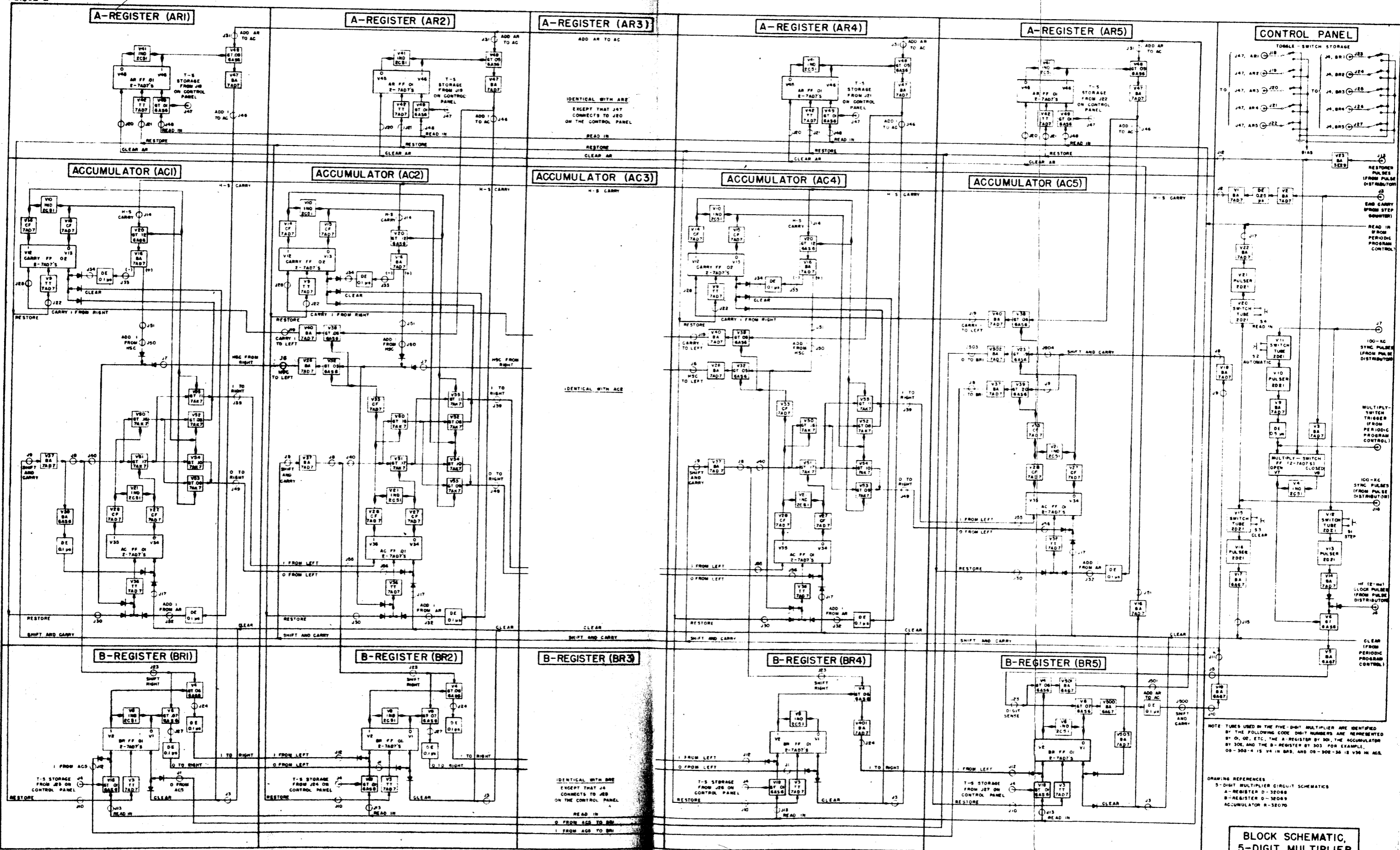


NOTES
 UNLESS OTHERWISE SPECIFIED, THE FOLLOWING SHALL APPLY TO ALL COMPONENTS IN THIS SCHEMATIC:
 1. RESISTORS ARE COMPOSITION TYPE, 1%, ±10%
 2. CAPACITORS ARE 50V, 50% CAPACITORS WHOSE VALUE IS NOT SPECIFIED ARE 0.002 MFD
 3. VACUUM CONNECTORS ARE TYPE MS-250/U
 4. CRYSTAL RECTIFIERS ARE TYPE 18A
 5. DELAY LINES ARE MADE UP FROM RG-58/U CABLE
 ALL TEST TUBE SOCKETS ARE WIRED FOR 6AS7'S AND ADAPTERS USED

DRAWING REFERENCES
 CIRCUIT SCHEMATIC, A-REGISTER, 8-DIGIT MULTIPLIER B-22008
 CIRCUIT SCHEMATIC, B-REGISTER, 8-DIGIT MULTIPLIER B-22008
 BLOCK SCHEMATIC, 8-DIGIT MULTIPLIER B-21008

CIRCUIT SCHEMATIC, ACCUMULATOR, FLIP-FLOP, 5-DIGIT MULTIPLIER TYPICAL DIGIT (DIGIT 2)

FIG. 15



NOTE: TUBES USED IN THE FIVE-DIGIT MULTIPLIER ARE IDENTIFIED BY THE FOLLOWING CODE (DIGIT NUMBERS ARE REPRESENTED BY 01, 02, ETC., THE A-REGISTER BY 001, THE ACCUMULATOR BY 002, AND THE B-REGISTER BY 003). FOR EXAMPLE, 05-308-4 IS V4 IN BR5, AND 05-308-36 IS V36 IN AC5.

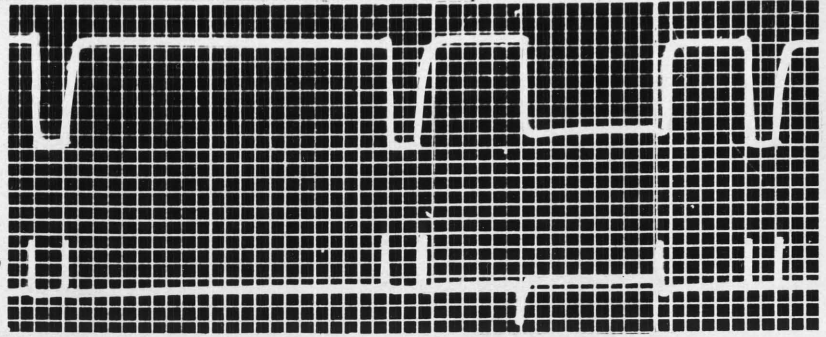
DRAWING REFERENCES
 5-DIGIT MULTIPLIER CIRCUIT SCHEMATICS
 A-REGISTER D-3008B
 B-REGISTER D-3009B
 ACCUMULATOR A-3070

BLOCK SCHEMATIC, 5-DIGIT MULTIPLIER

STEPS 4 & 5 : CLEAR AND READ IN

UPPER : BR 5 FF
WAVEFORMS
1-0-1

LOWER : RESTORER PULSES
CLEAR PULSE
READ-IN PULSE

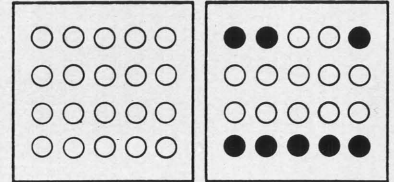


STEP 6 : CHECK REGISTERS

LEFT : ALL DIGITS CLEARED
RIGHT : AR 11001
BR 11111
BOTTOM : STEP COUNTER 110

● = 1
○ = 0

AR
CARRY
AC
BR



STEP COUNTER

STEP 7 : MULTIPLY

MULTIPLY-SWITCH
FF

MULTIPLY PULSE

CLOCK PULSES
AT
MULTIPLY GATE

CLOCK PULSES
PASSED BY
MULTIPLY GATE

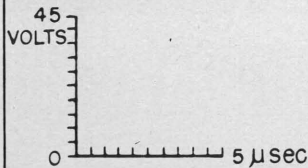
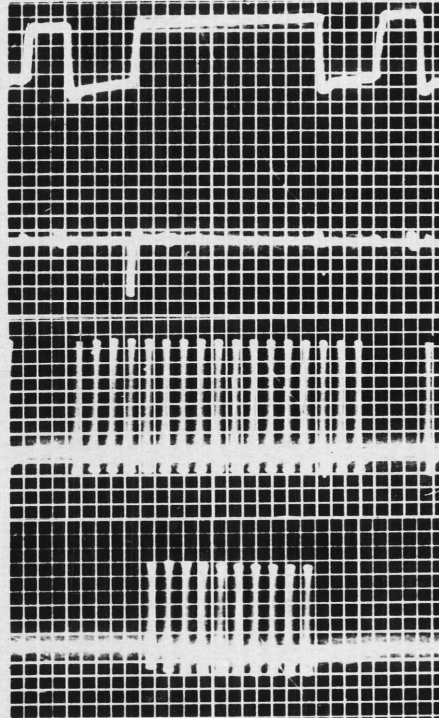


FIGURE 17
PRELIMINARY STEPS 4-7

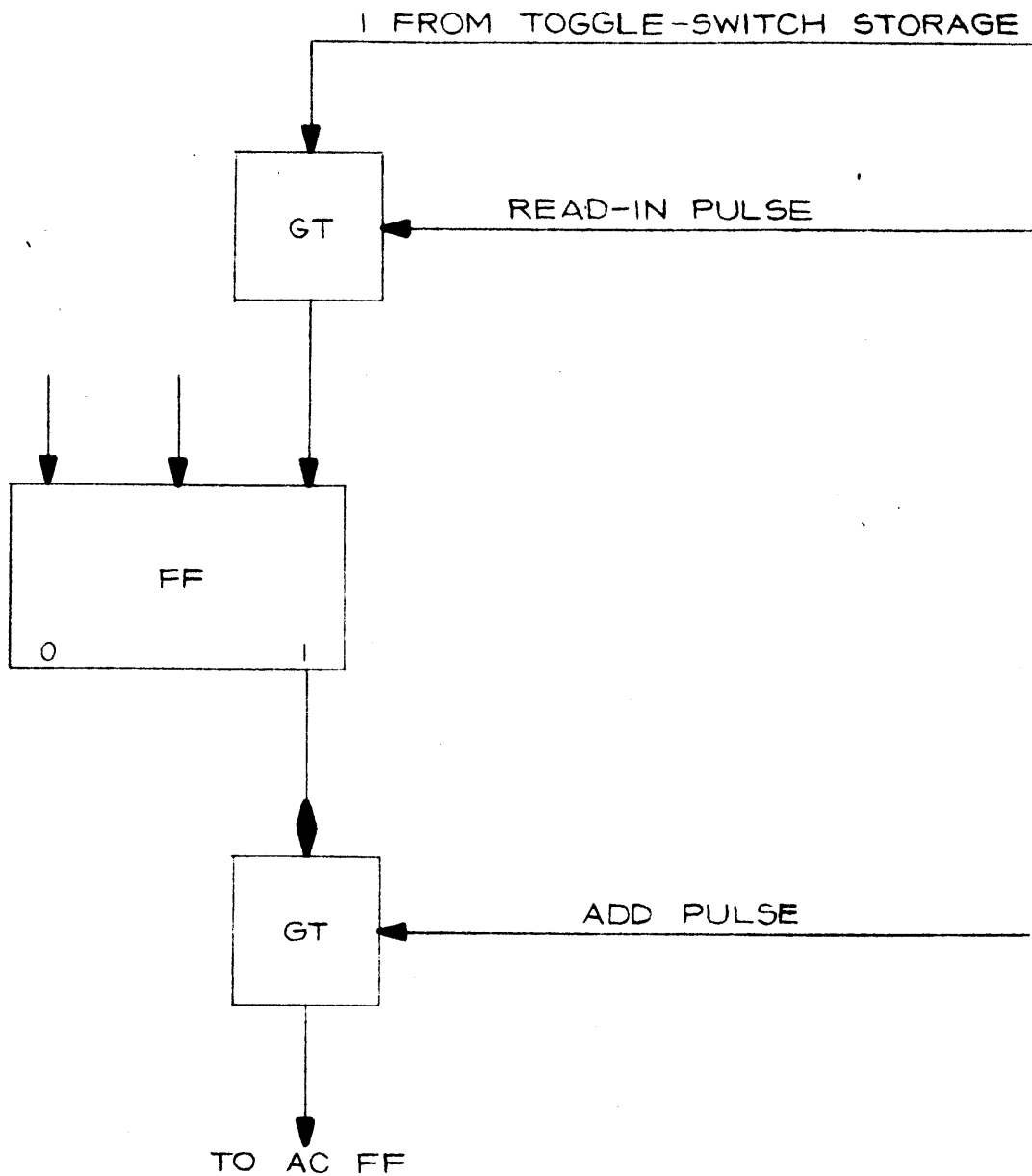


FIG. 18
GATE PASSING A READ-IN PULSE

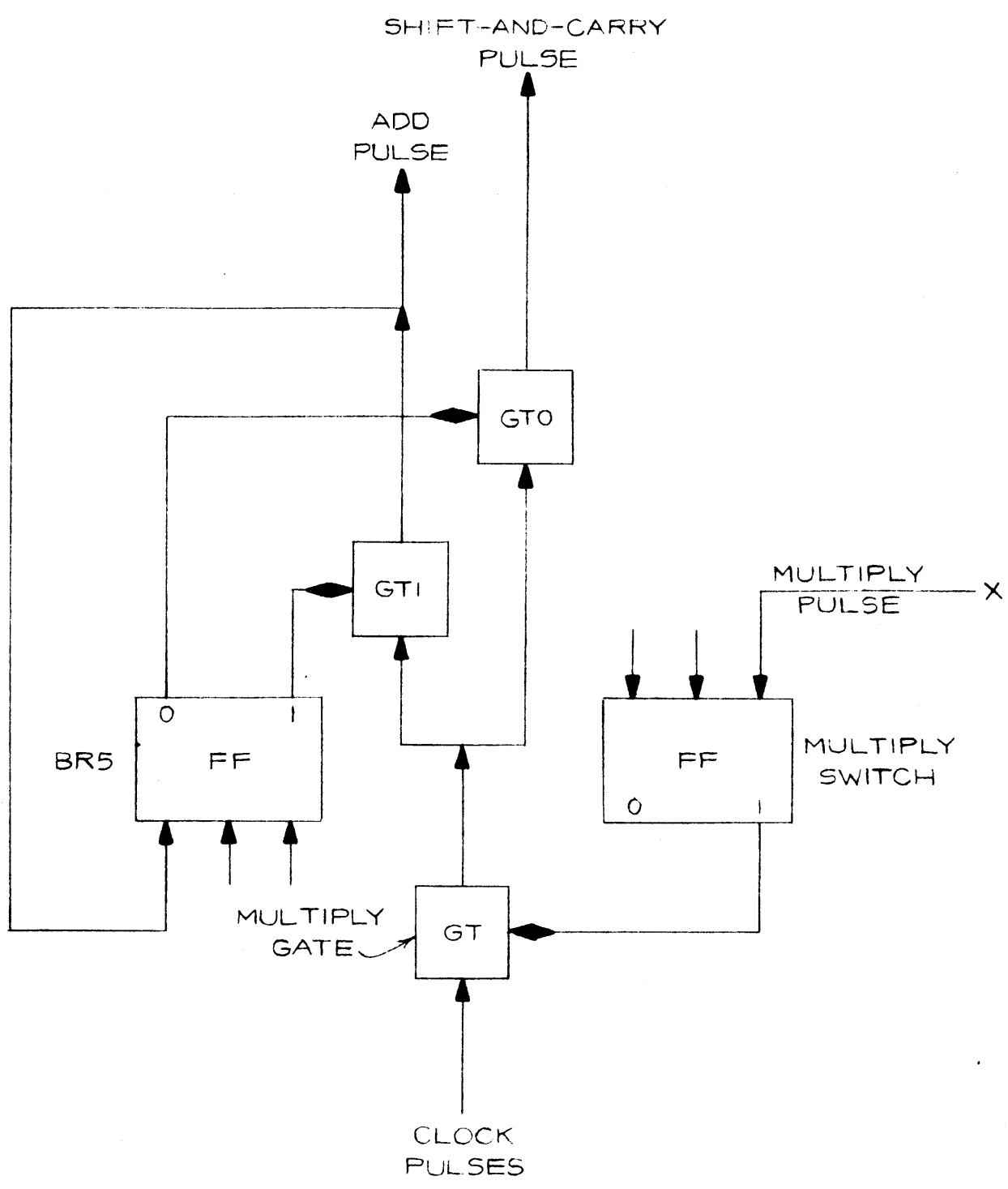
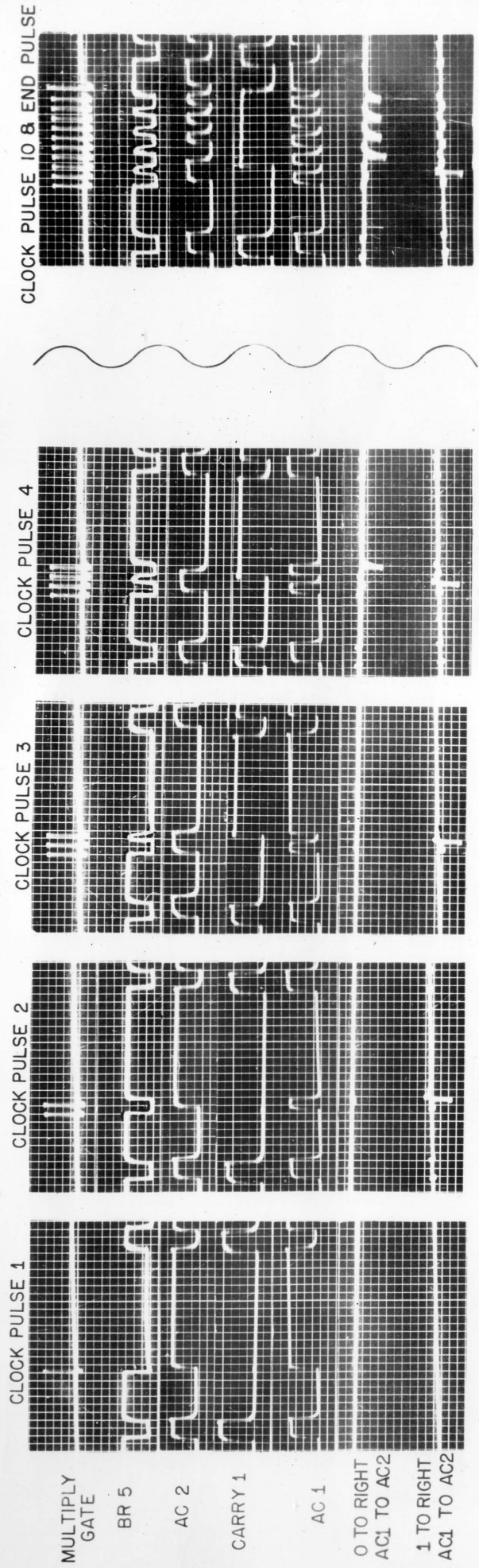
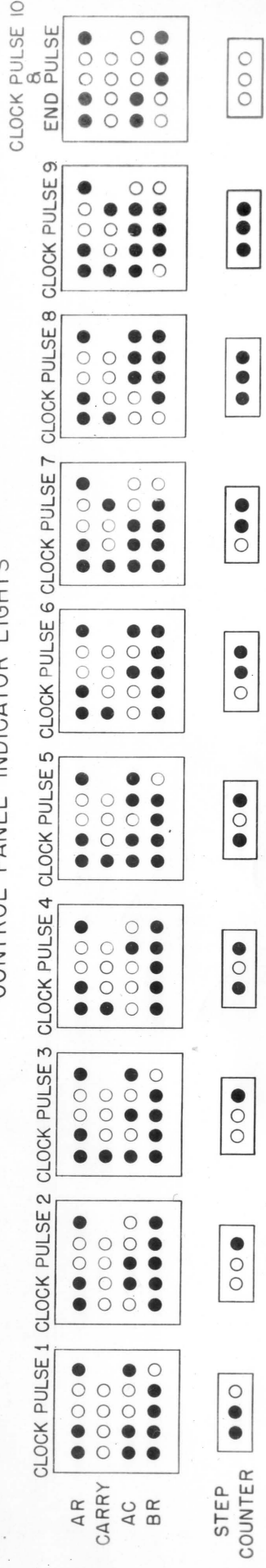


FIG. 19
ACTION OF MULTIPLY PULSE

PULSE AND WAVEFORM BEHAVIOR



CONTROL PANEL INDICATOR LIGHTS



LEGEND ● = 1
○ = 0

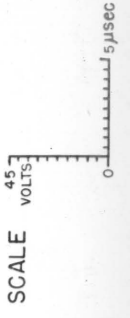


FIGURE 20
FLIP-FLOP POSITIONS DURING SOLUTION
OF PROBLEM 25 X 31

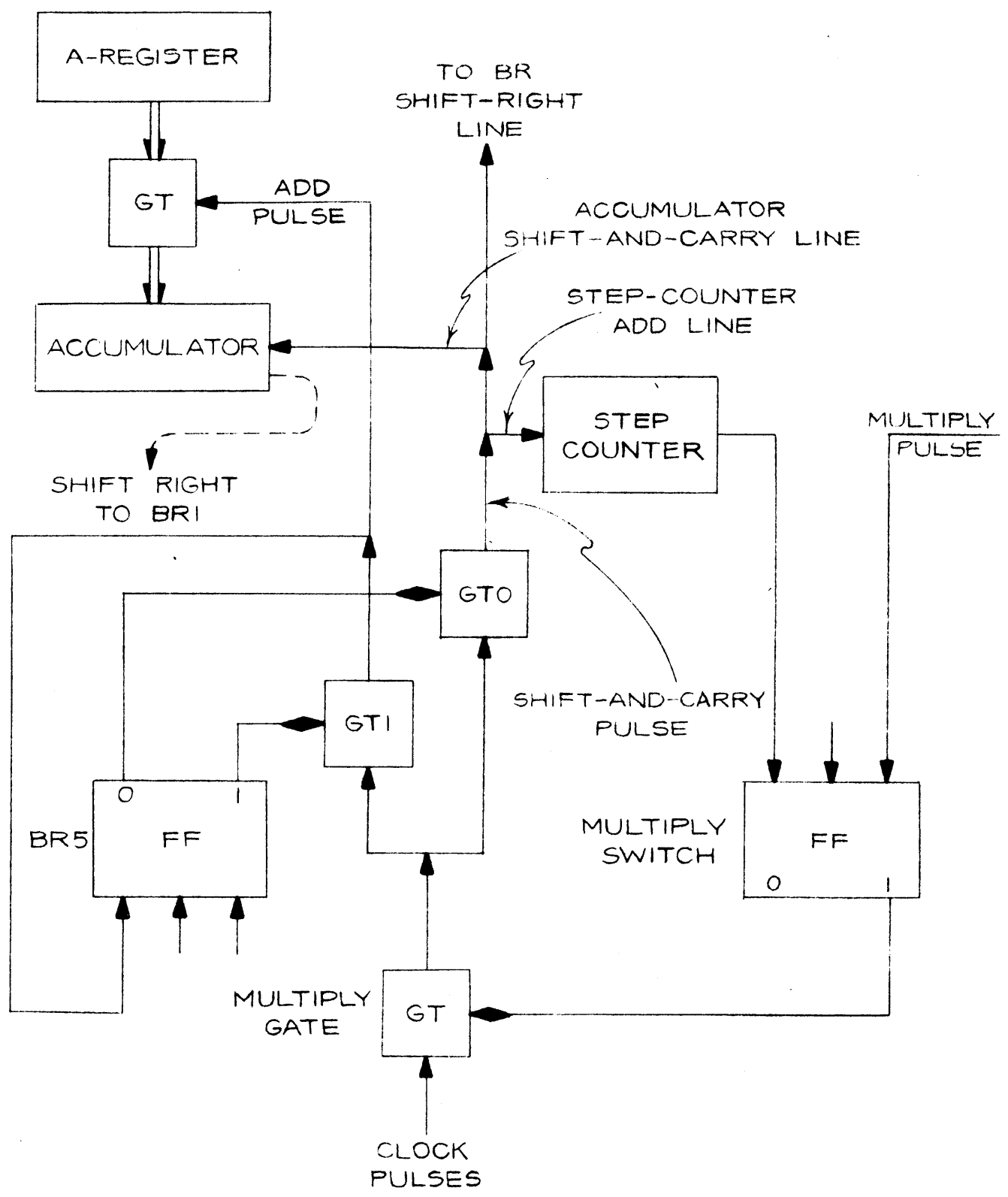


FIG. 21
SENSING, BR5

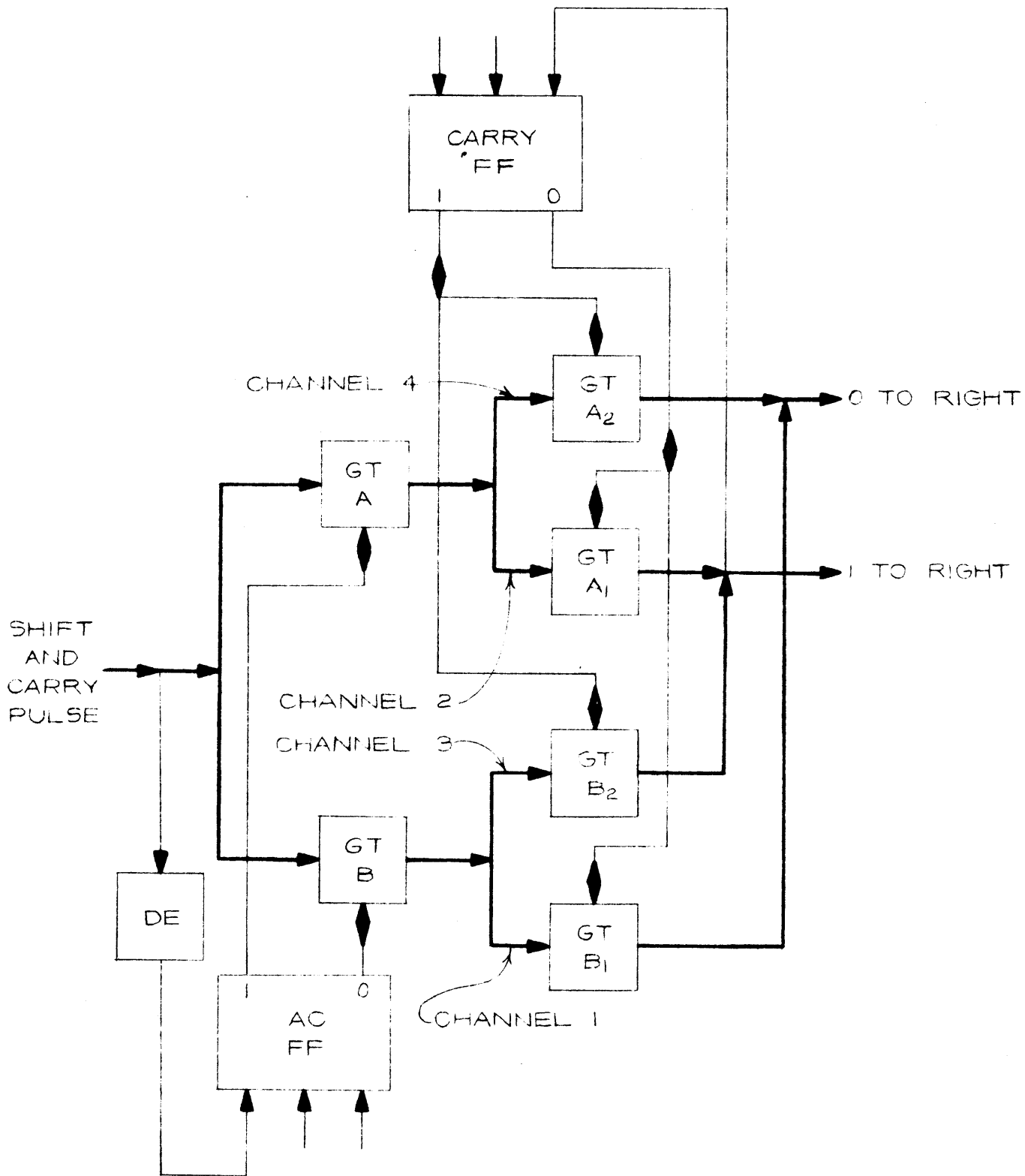


FIG. 28
WHIFFLETREE CIRCUIT, ACI

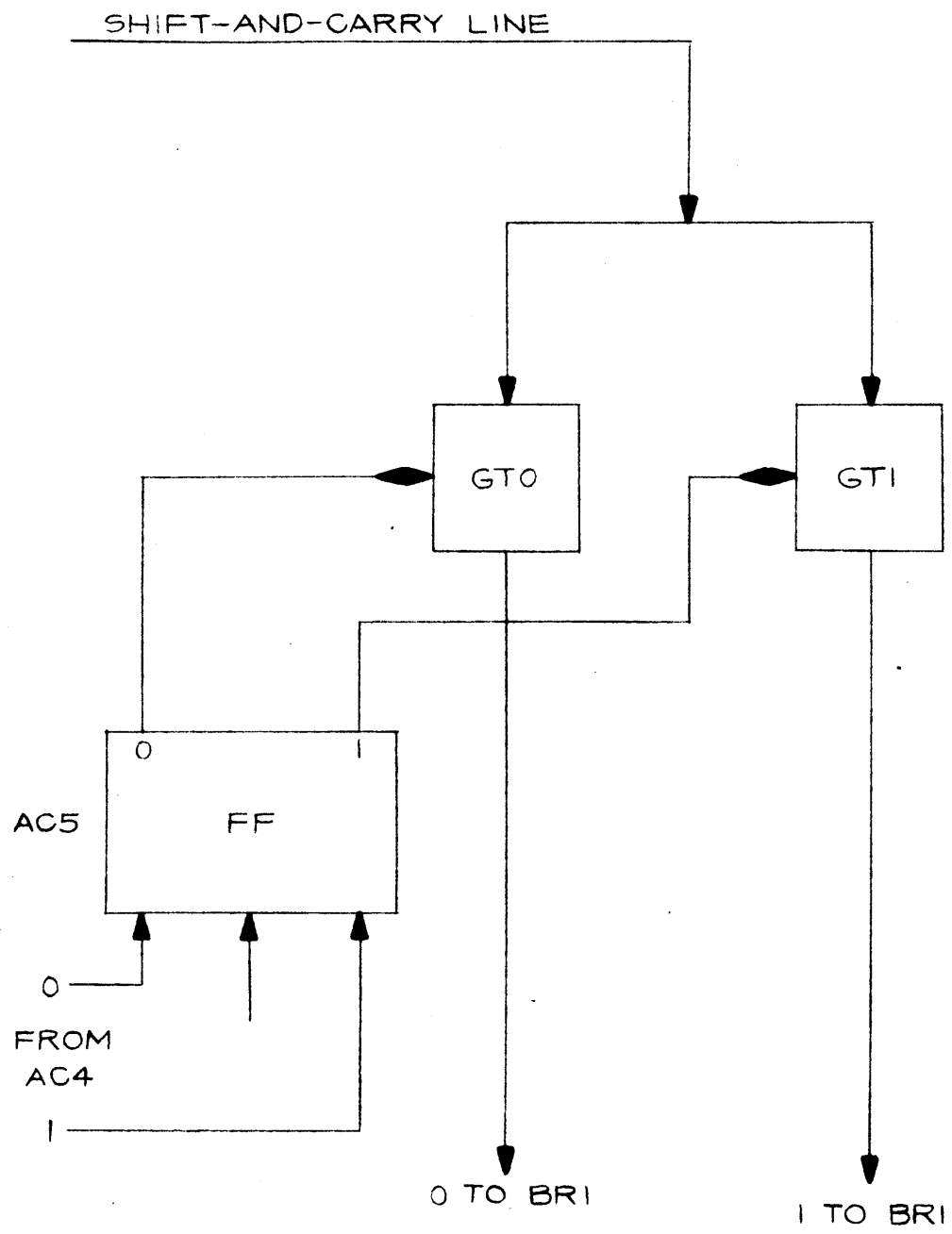


FIG. 23
SHIFT RIGHT, AC5

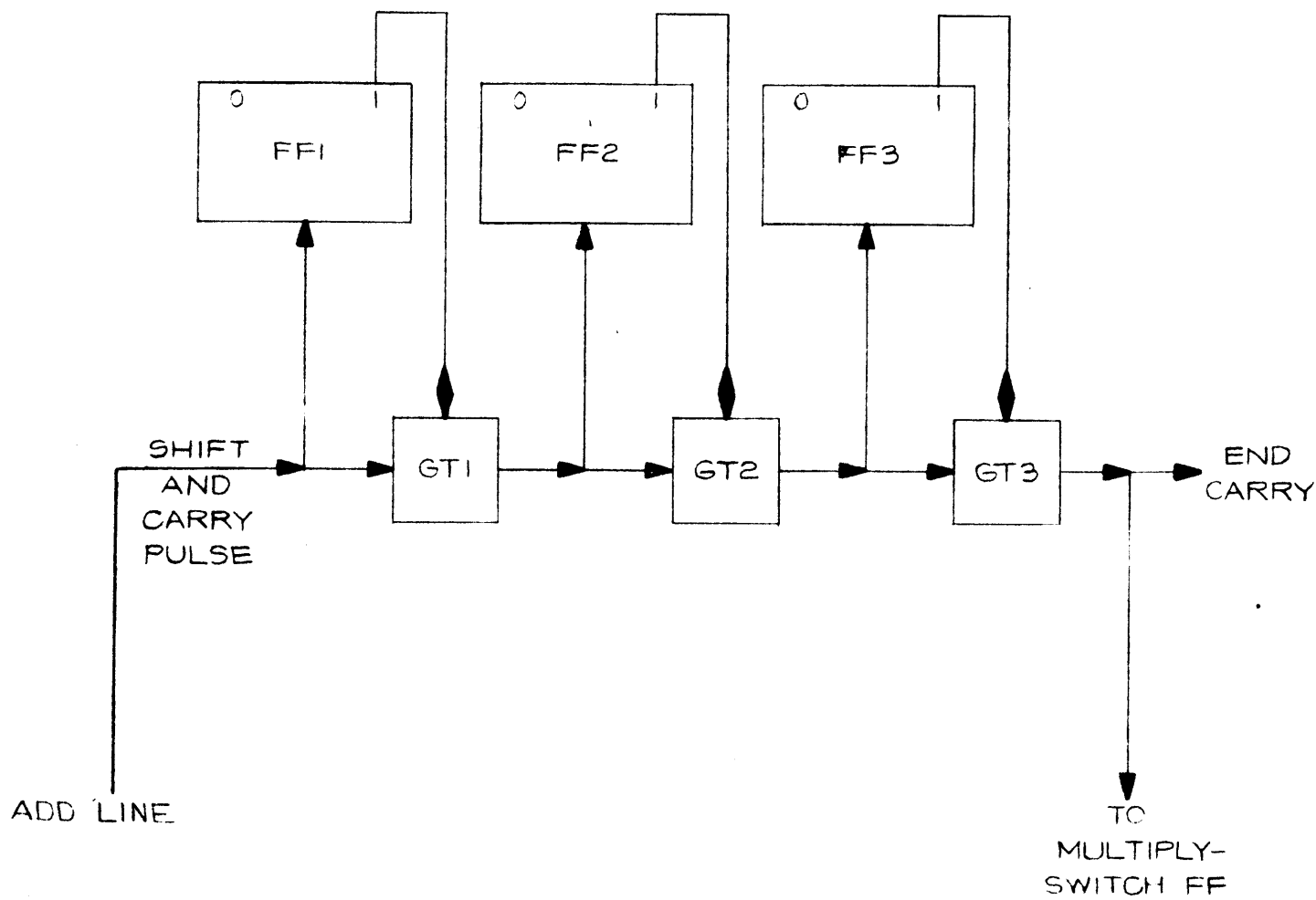


FIG. 24
STEP COUNTER

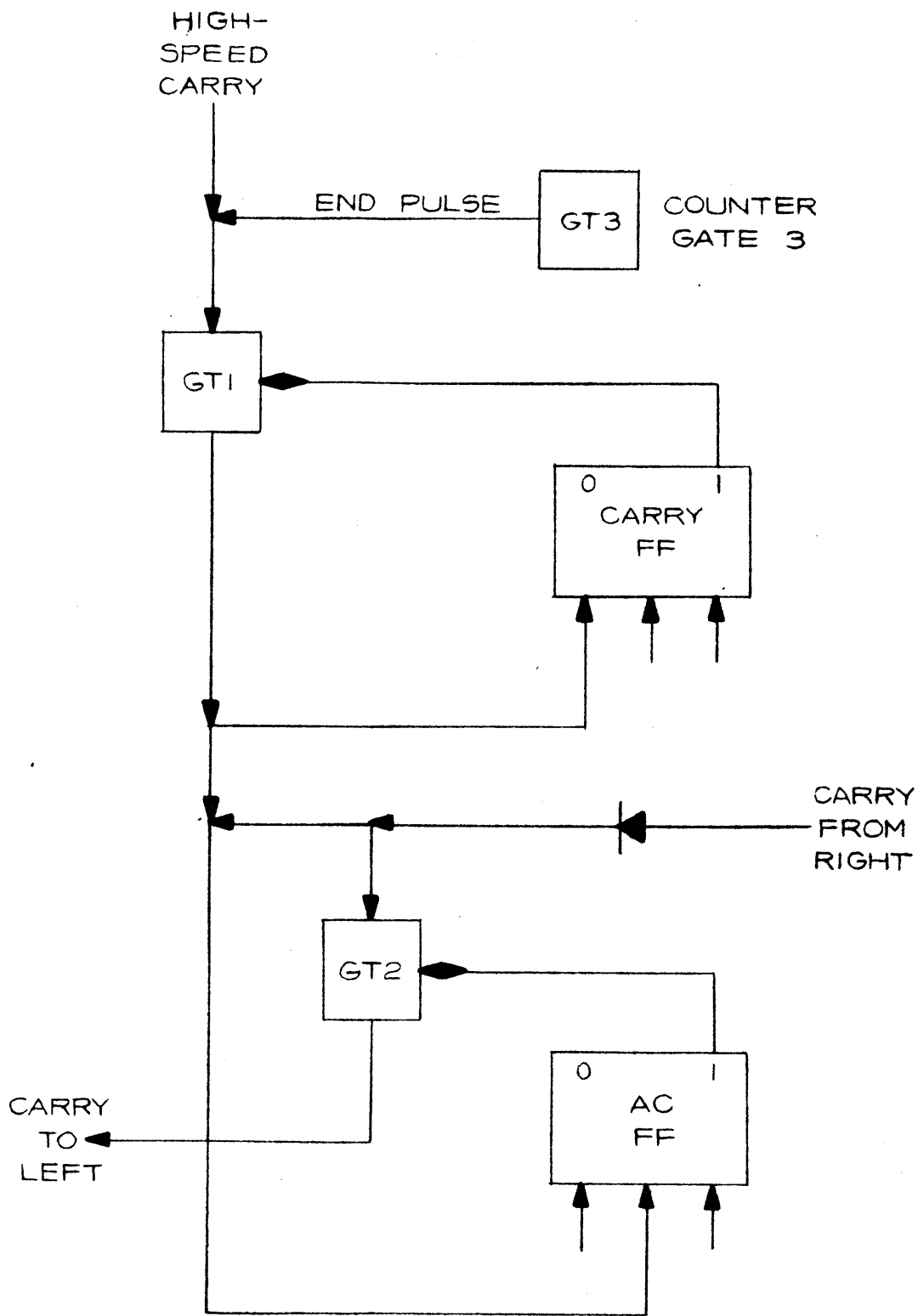


FIG. 26
HIGH-SPEED CARRY

KEUFFEL & ESSER CO., N. Y. NO. 385T-51C
 10 X 10 to the Inch.
 MADE IN U.S.A.

	A-REGISTER					ACCUMULATOR										B-REGISTER				
	READ IN ADD TO AC			WHIFFLETREE					CARRY TO LEFT			HS CARRY				S&C	SR GATES		READ IN	
	GT	BA	GT	GT	GT	GT	GT	GT	GT	GT	BA	GT	BA	GT	BA	BA	GT	GT	GT	
	V49	V47	V48	V50	V51	V52	V53	V54	V55	V38	V40	V20	V16	V32	V26	V37	V6	V4	V18	
DIGIT COLUMN	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	2 3 4 5	2 3 4 5	1 2 3 4	2 3 4	2 3 4	1 2 3 4	1 2 3 4	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	
PROBLEM 1																				
(1111 x 1111)	✓✓✓✓✓																		✓✓✓✓✓	
STEP 1 ADD		✓✓✓✓✓	✓✓✓✓✓																✓	
STEP 2 S&C				✓✓✓✓✓	xxxxx	✓✓✓✓✓	xxxxx										✓✓✓✓✓	xxxxx	✓✓✓✓✓	
STEP 3 ADD		✓✓✓✓✓	✓✓✓✓✓																✓	
STEP 4 S&C				✓	✓✓✓✓✓		✓	xxx	✓✓✓								✓✓✓✓✓	✓✓✓✓✓		
STEP 5 ADD		✓✓✓✓✓	✓✓✓✓✓																✓	
STEP 6 S&C				✓✓	✓✓✓		✓✓		✓✓								✓✓✓✓✓	✓	✓✓✓✓✓	
STEP 7 ADD		✓✓✓✓✓	✓✓✓✓✓																✓	
STEP 8 S&C				✓✓✓		✓✓	✓✓✓		✓								✓✓✓✓✓	✓✓	✓✓✓	
STEP 9 ADD		✓✓✓✓✓	✓✓✓✓✓																✓	
STEP 10 S&C				✓✓✓✓✓		xxxxx	✓✓✓✓✓										✓✓✓✓✓	✓✓✓	✓✓	
STEP 11 HSC												✓✓✓✓✓	✓✓✓	xxx						
PROBLEM 2																				
(11011 x 10011)	✓✓x✓✓✓																		✓x✓✓✓✓	
STEP 1 ADD		✓✓✓✓✓	✓✓✓✓✓																✓	
STEP 2 S&C				✓x✓✓✓	xxx	xxx		xxx	✓x✓✓									✓✓	✓✓	✓
STEP 3 ADD		✓✓✓✓✓	✓✓✓✓✓																✓	
STEP 4 S&C				✓✓✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓✓✓✓✓			
STEP 5 S&C				✓	✓✓✓	✓		✓	✓✓	✓							✓	✓✓	✓✓	
STEP 6 S&C				✓	✓✓✓	✓		✓✓	✓								✓✓	✓	✓✓	
STEP 7 ADD		✓✓✓✓✓	✓✓✓✓✓																✓	
STEP 8 S&C				✓✓✓✓✓		✓✓✓✓✓	✓										✓✓✓✓✓	✓	✓	
STEP 9 HSC																	✓✓✓	✓✓✓		
PROBLEM 3																				
(00010 x 00010)	xxx✓✓✓																		xxxxx	
STEP 1 ADD		✓	xxxxx																✓	
STEP 2 S&C				✓	✓✓✓	✓	✓	✓✓✓	xxxxx								✓✓✓✓✓	xxxxx	✓	
STEP 3 S&C				✓✓✓✓✓				✓✓✓✓✓	xxxxx								✓✓✓✓✓			
STEP 4 S&C				xxxxx	✓✓✓✓✓			✓✓✓✓✓									✓✓✓✓✓			
STEP 5 S&C					✓✓✓✓✓			✓✓✓✓✓									✓	✓✓✓	✓	
STEP 6 S&C					✓✓✓✓✓			✓✓✓✓✓									✓✓	✓✓	✓	
STEP 7 HSC												xxxxx					✓✓	✓✓	✓	

KEY

- (✓) INDICATES ABILITY OF GATE TUBE TO PASS A PULSE.
- (x) INDICATES ABILITY OF FF AND GATE TO REJECT A PULSE (TYPICAL EXAMPLES NOTED).

FIGURE 27 TEST PROBLEMS