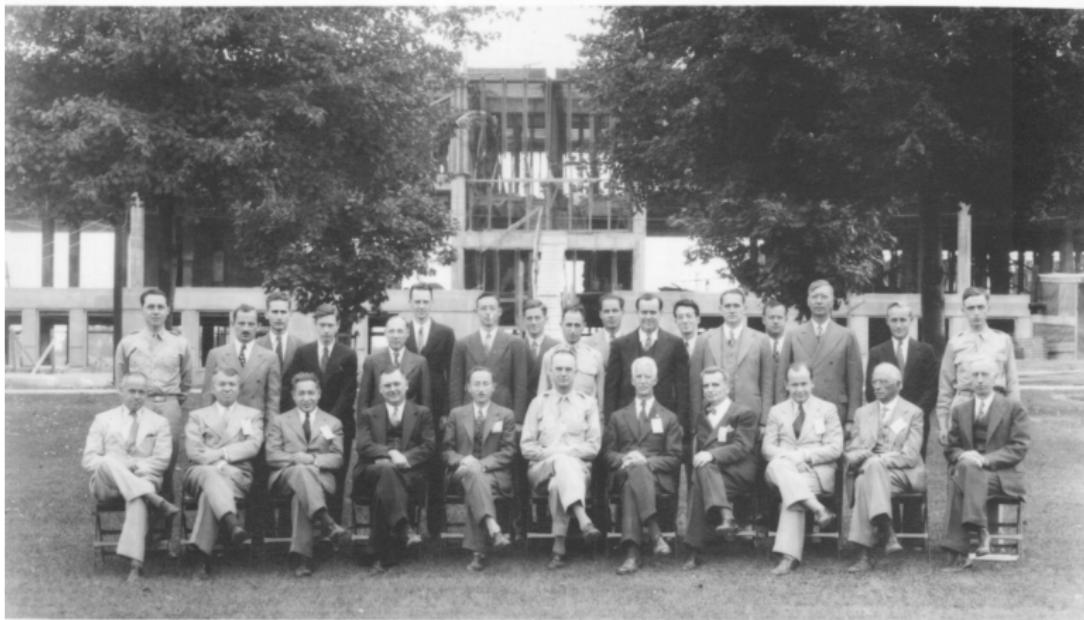


# Hidden Pioneers: Programmers of the ENIAC and the Birth of Modern Computing

Nelson Jovel • Education Commonwealth Project •  
[joveln@gmail.com](mailto:joveln@gmail.com)

FIRST MEETING OF THE SCIENTIFIC ADVISORY COMMITTEE  
BALLISTIC RESEARCH LABORATORY SEPTEMBER 1940



Lt. Gillon	Mr. Moerman	Mr. Dickinson	Mr. Carr	Mr. McNeilly	Mr. Shanks	Mr. Leeder	Lt. Steele			
Mr. Lane	Mr. Reno	Mr. Hitchcock	Dr. Charters	Capt. Simon	Dr. Hodge	Mr. Beeman	Mr. Toich	Mr. Gay		
Mr. Kent	Prof. Urey	Prof. Rabi	Dr. Dryden	Dr. Lewis	Col. Zornig	Dr. Hull	Prof. von Karman	Prof. von Neumann	Prof. Russell	Dr. Dederick

Howitzer

## Example Artillary

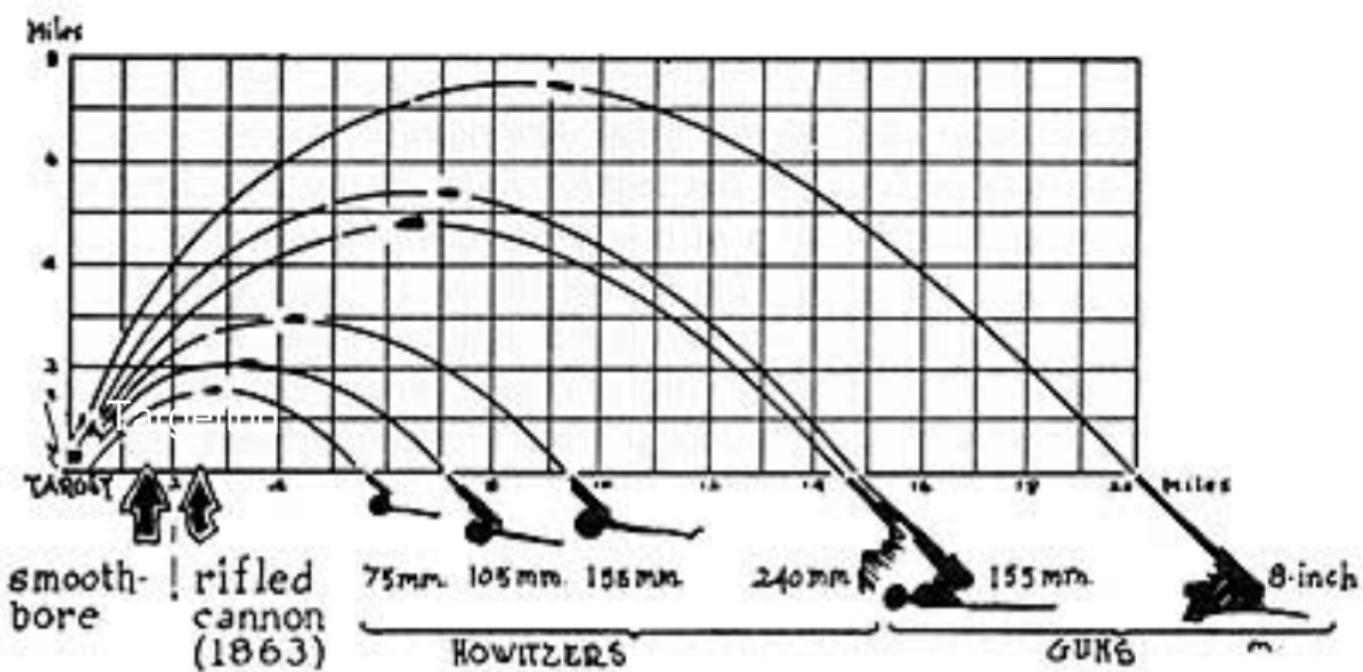


Tank



Anti-Aircraft





600	30.6	1.9	1.06	19	1	1.9	0.3	0.03
700	35.8	2.2	0.91	19	1	2.3	0.4	0.03
800	41.1	2.5	0.79	19	1	2.6	0.5	0.04
900	46.4	2.8	0.71	19	1	2.9	0.6	0.04
1000	51.7	3.2	0.63	19	1	3.2	0.7	0.04
1100	57.1	3.5	0.57	19	1	3.6	0.8	0.05
1200	62.5	3.8	0.53	18	1	3.9	0.8	0.05
1300	67.9	4.2	0.48	18	1	4.3	0.9	0.05
1400	73.4	4.5	0.45	18	1	4.6	1.0	0.06
1500	78.9	4.9	0.42	18	1	4.9	1.1	0.06
1600	84.4	5.2	0.39	18	2	5.3	1.2	0.07
1700	90.0	5.5	0.37	18	2	5.8	1.3	0.07
1800	95.6	5.9	0.35	18	2	6.0	1.4	0.07
1900	101.3	6.2	0.33	18	2	6.3	1.6	0.08
2000	107.0	6.6	0.31	17	2	6.7	1.7	0.08
2100	112.8	6.9	0.30	17	2	7.0	1.8	0.08
2200	118.5	7.3	0.28	17	2	7.4	1.9	0.09
2300	124.4	7.6	0.27	17	2	7.7	2.0	0.09
2400	130.3	8.0	0.26	17	2	8.1	2.1	0.09
2500	136.2	8.3	0.25	17	2	8.4	2.2	0.10
2600	142.2	8.7	0.24	17	2	8.8	2.3	0.10
2700	148.2	9.1	0.23	17	2	9.2	2.5	0.10
2800	154.3	9.4	0.22	16	2	9.5	2.6	0.11
2900	160.4	9.8	0.21	16	3	9.9	2.7	0.11
3000	166.6	10.2	0.20	16	3	10.3	2.9	0.12
mean	172.8	10.6	0.20	16	3	10.6	3.0	0.12

FT 155-AM-2

TABLE H

CHARGE  
4GPROJ, HE, M107  
FUZE, PD, M577

## ROTATION - RANGE

CORRECTIONS TO RANGE, IN METERS, TO COMPENSATE  
FOR THE ROTATION OF THE EARTH

RANGE METERS	AZIMUTH OF TARGET - MILS									
	0 3200	200 3000	400 2800	600 2600	800 2400	1000 2200	1200 2000	1400 1800	1600 1600	
500	0	0	-1+	-1+	-2+	-2+	-2+	-2+	-2+	
1000	0	-1+	-2+	-2+	-3+	-4+	-4+	-4+	-4+	
1500	0	-1+	-3+	-4+	-5+	-5+	-6+	-6+	-7+	
2000	0	-2+	-3+	-5+	-6+	-7+	-8+	-8+	-9+	
2500	0	-2+	-4+	-6+	-7+	-9+	-10+	-10+	-10+	
3000	0	-2+	-5+	-7+	-9+	-10+	-11+	-12+	-12+	
3500	0	-3+	-5+	-8+	-10+	-12+	-13+	-14+	-14+	
4000	0	-3+	-6+	-9+	-11+	-13+	-14+	-15+	-15+	
4500	0	-3+	-8+	-9+	-12+	-14+	-16+	-16+	-17+	
5000	0	-4+	-7+	-10+	-13+	-15+	-17+	-18+	-18+	
5500	0	-4+	-7+	-11+	-14+	-16+	-18+	-19+	-19+	
6000	0	-4+	-8+	-11+	-14+	-17+	-18+	-20+	-20+	
6500	0	-4+	-8+	-11+	-14+	-17+	-19+	-20+	-20+	
7000	0	-4+	-8+	-11+	-15+	-17+	-19+	-20+	-21+	
7500	0	-4+	-8+	-11+	-14+	-17+	-18+	-20+	-20+	
8000	0	-3+	-7+	-10+	-13+	-15+	-16+	-17+	-18+	

COMPUTING  
DIVISION  
COMPUTING  
SECTION

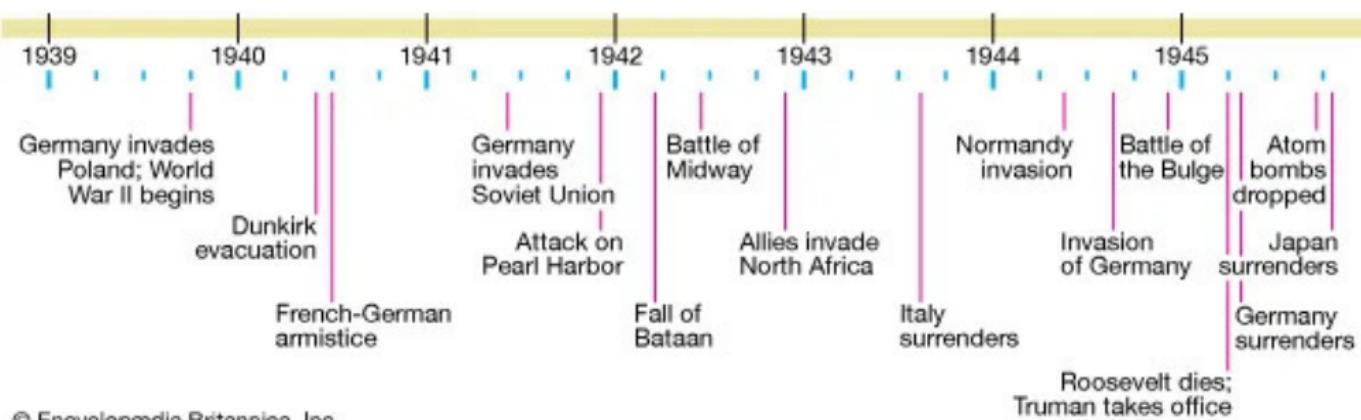


# DIFFERENTIAL ANALYZER





## Chief Events of World War II, 1939–45



© Encyclopædia Britannica, Inc.





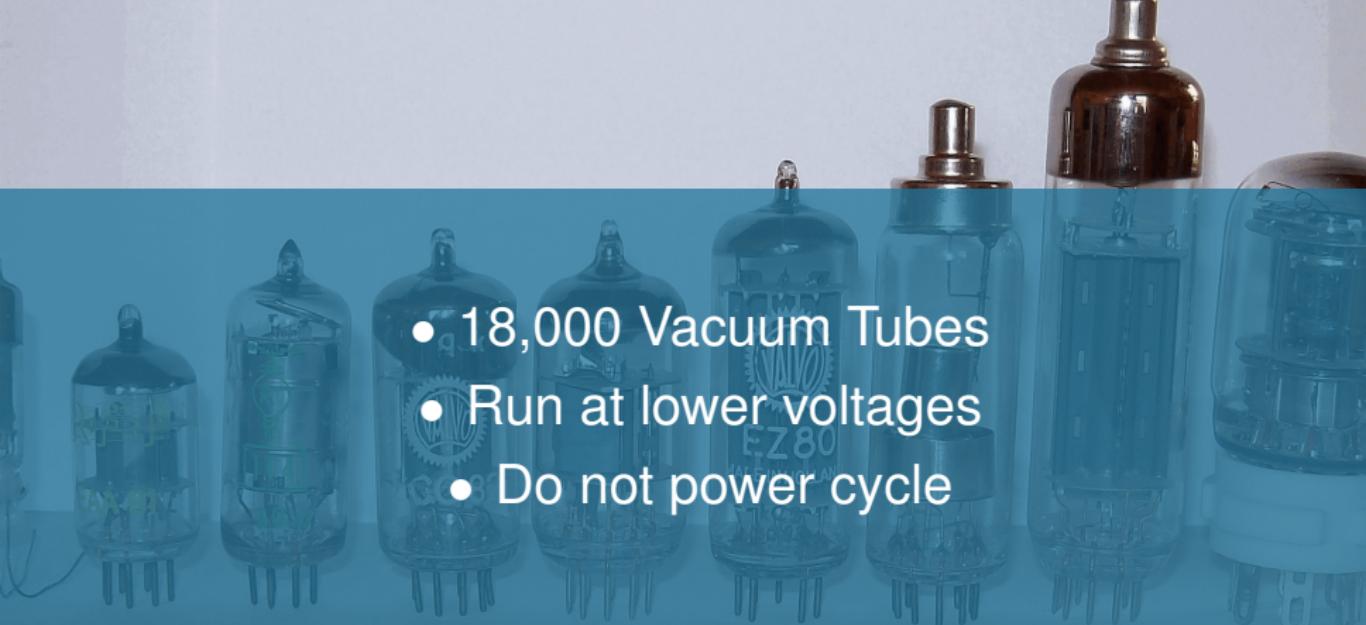
- Designers: John Mauchley and J. Presper Eckert

- The Use of High Speed Vacuum Tube Devices for Calculating
- 1000 times faster than the differential analyzer
  - General Purpose computer



- Projected Cost: 61,000
- Actual Cost: 500,000
- Today: 9,000,000+



- 
- 18,000 Vacuum Tubes
  - Run at lower voltages
    - Do not power cycle





# • ENIAC



• ENIAC  
• BINAC

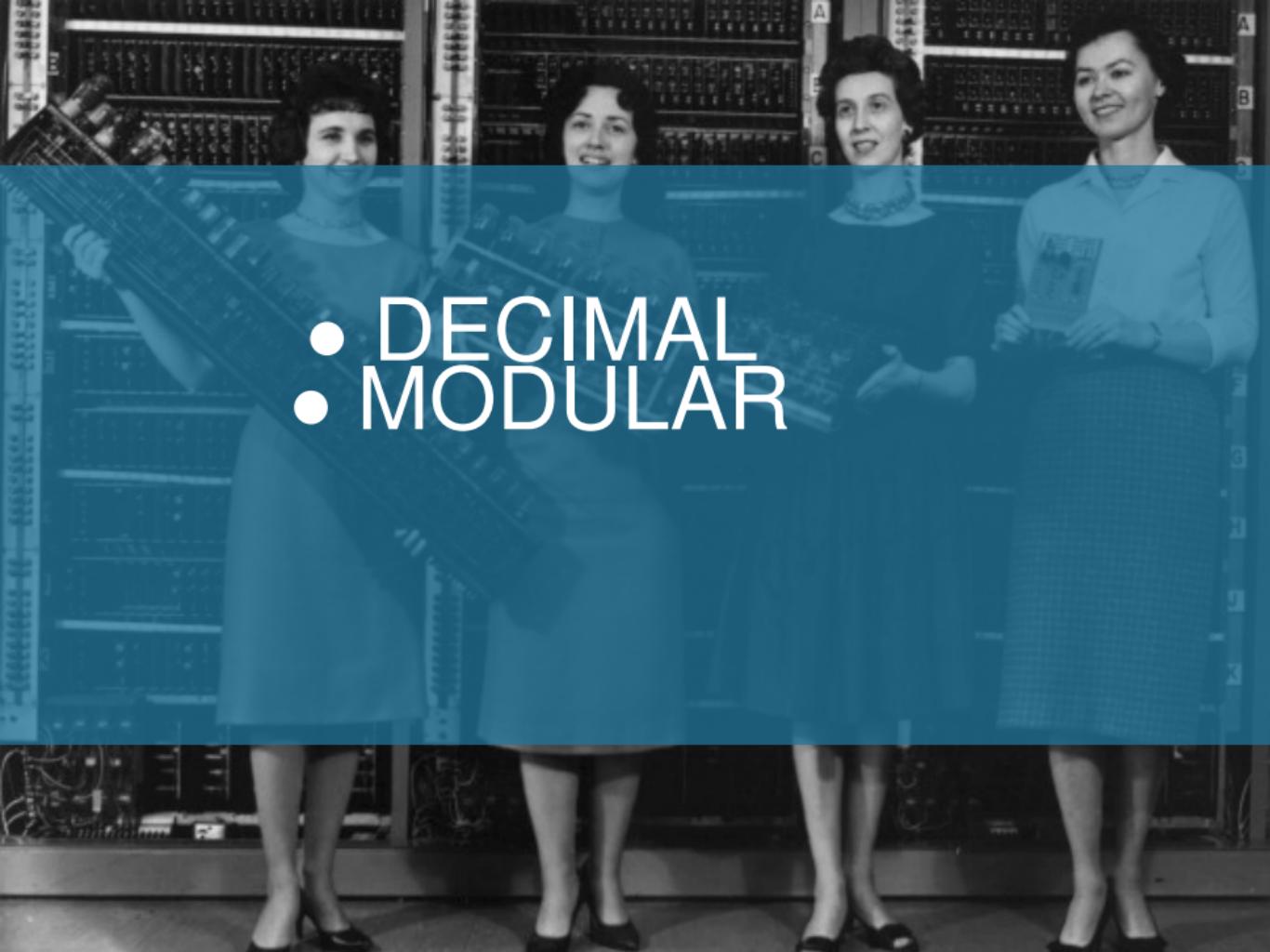
- 
- ENIAC
  - BINAC
  - EDVAC

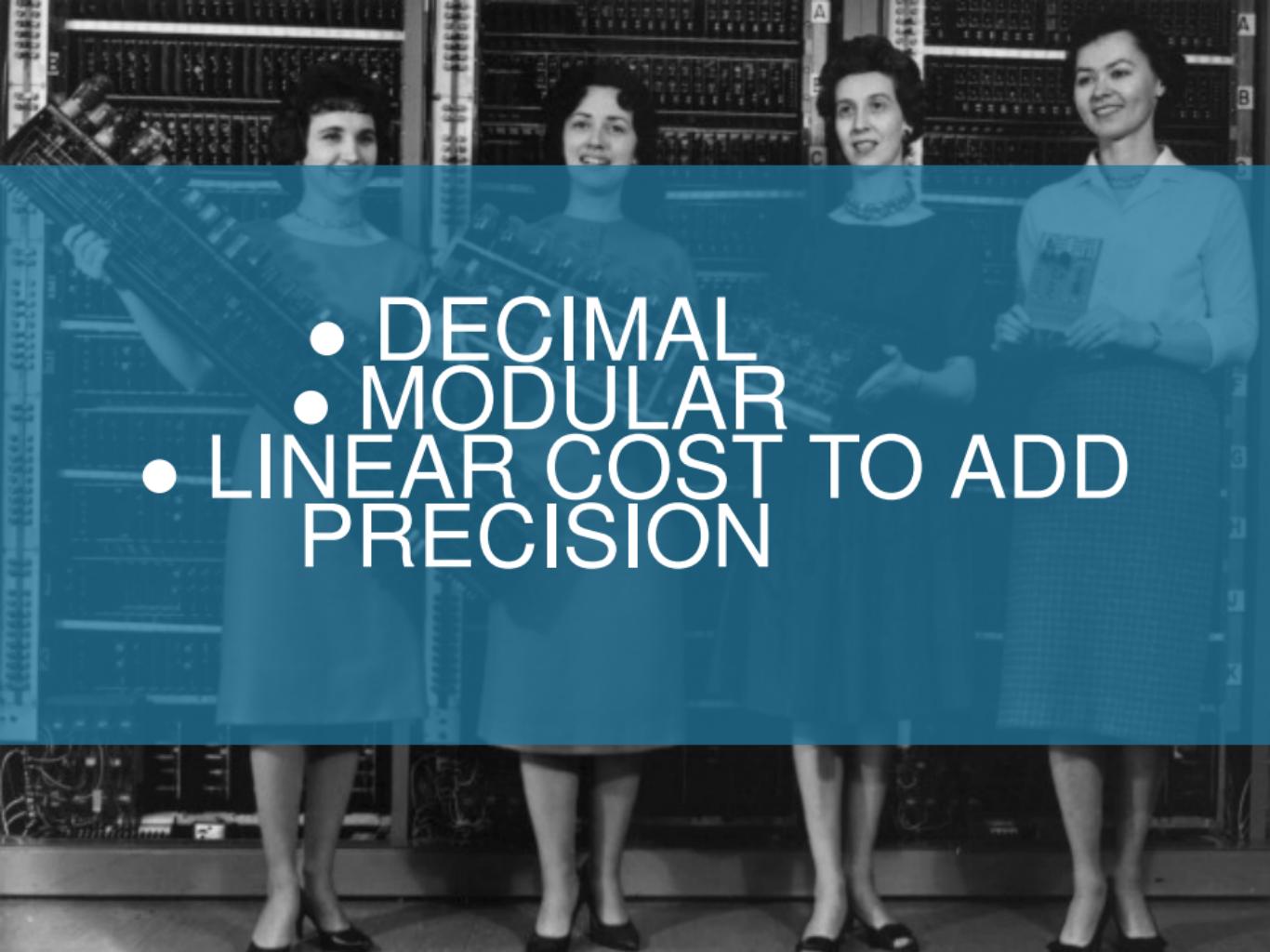
- ENIAC
- BINAC
- EDVAC
- UNIVAC





## • DECIMAL

- 
- DECIMAL
  - MODULAR

- 
- DECIMAL
  - MODULAR
  - LINEAR COST TO ADD  
PRECISION

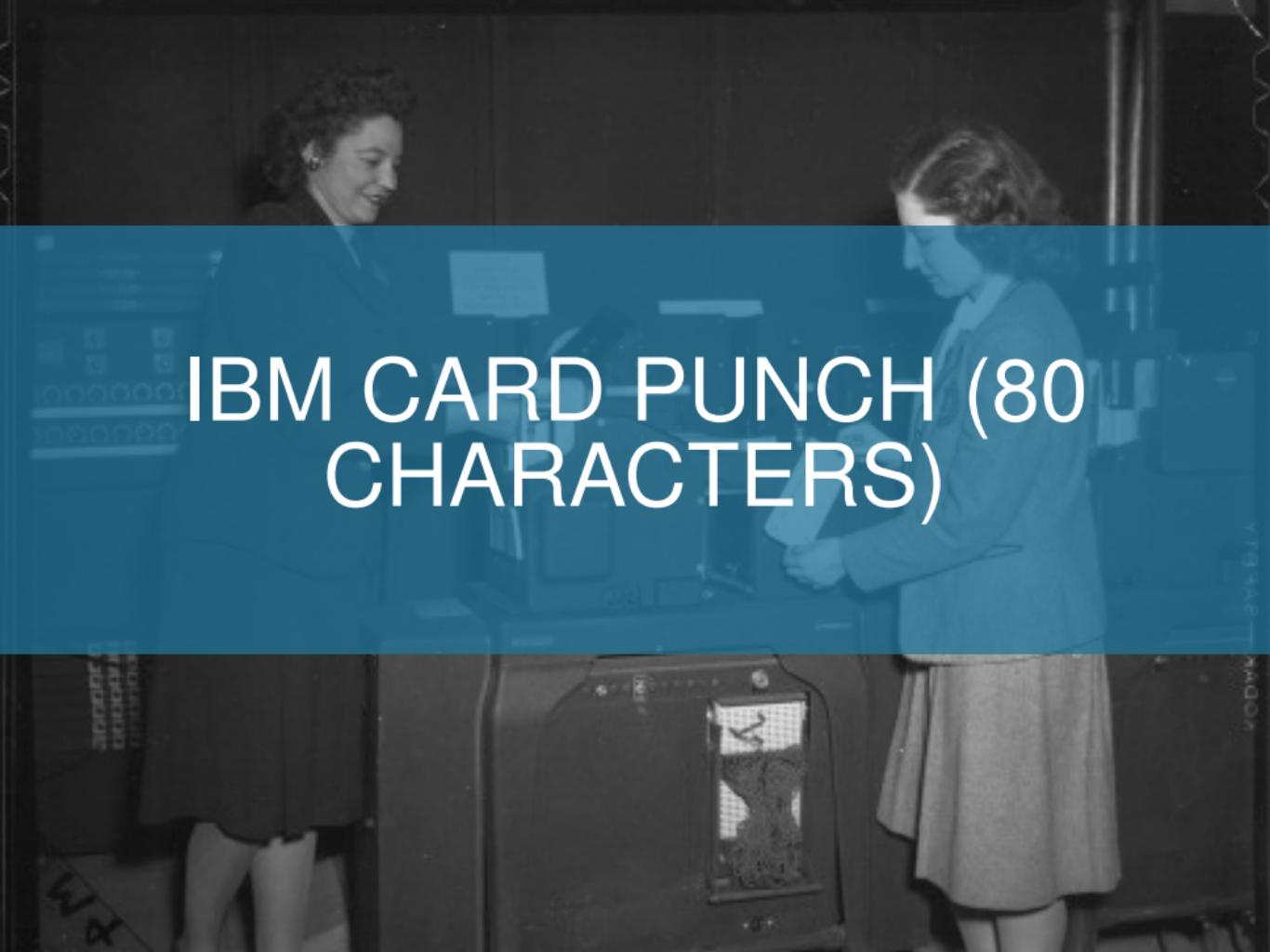




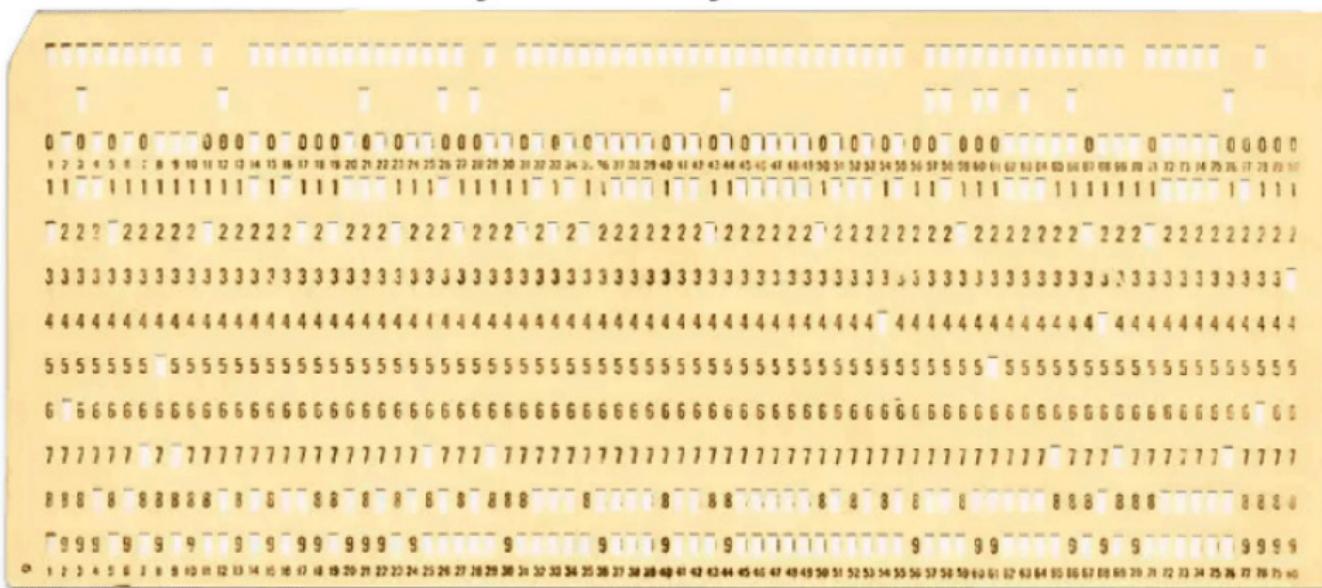
D  
DATA  
ENCL  
1  
1  
1

W  
K

# IBM CARD PUNCH (80 CHARACTERS)



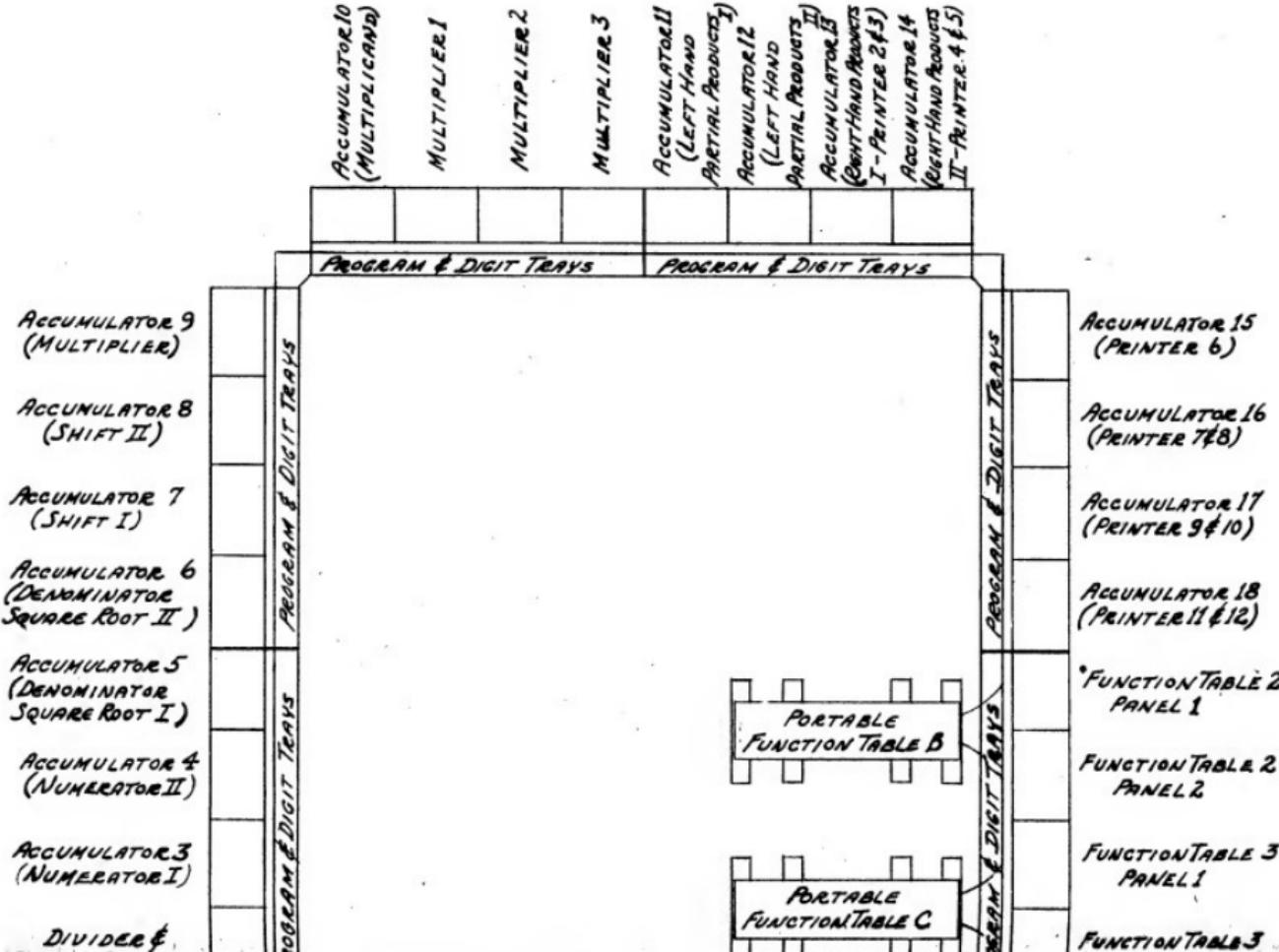
## Example of a punch card



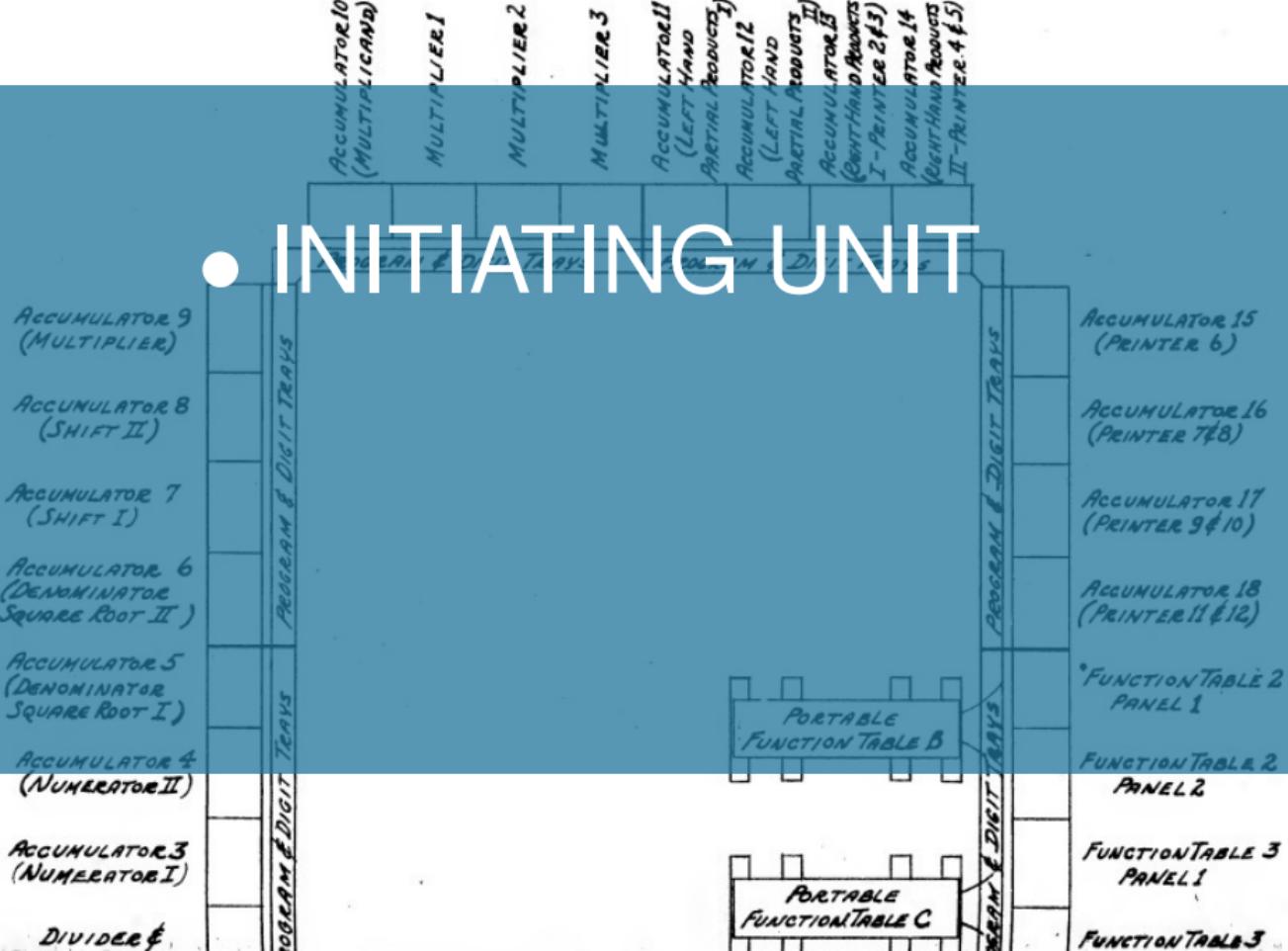


A black and white photograph of a woman from the mid-20th century. She has dark, curly hair and is wearing a dark, long-sleeved dress with a row of buttons down the front. A pearl necklace is visible around her neck. She is standing behind a massive, sprawling stack of paper, which appears to be several thousand pages thick. In the background, there's a filing cabinet and some office equipment. The entire scene is overlaid with a solid blue rectangular shape.

5MB OF DATA



# • INITIATING UNIT



# • INITIATING UNIT • CYCLING UNIT

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4

ACCUMULATOR 10  
(MULTICANDIDATE)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
(LEFT HAND  
PARTIAL PRODUCTS)

ACCUMULATOR 12  
(LEFT HAND  
PARTIAL PRODUCTS)

ACCUMULATOR 13  
(LEFT HAND  
PARTIAL PRODUCTS)

ACCUMULATOR 14  
(LEFT-HAND PRODUCTS  
I - PENTER 2 & 3)

ACCUMULATOR 15  
(LEFT-HAND PRODUCTS  
II - PENTER 4 & 5)

ACCUMULATOR 15  
(PENTER 6)

ACCUMULATOR 16  
(PENTER 7 & 8)

ACCUMULATOR 17  
(PENTER 9 & 10)

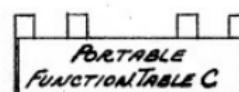
ACCUMULATOR 18  
(PENTER 11 & 12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



# • INITIATING UNIT • CYCLING UNIT • MASTER PROGRAMMER

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4



ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

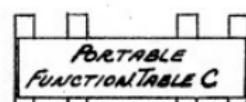
ACCUMULATOR 18  
(PRINTER 11&12)

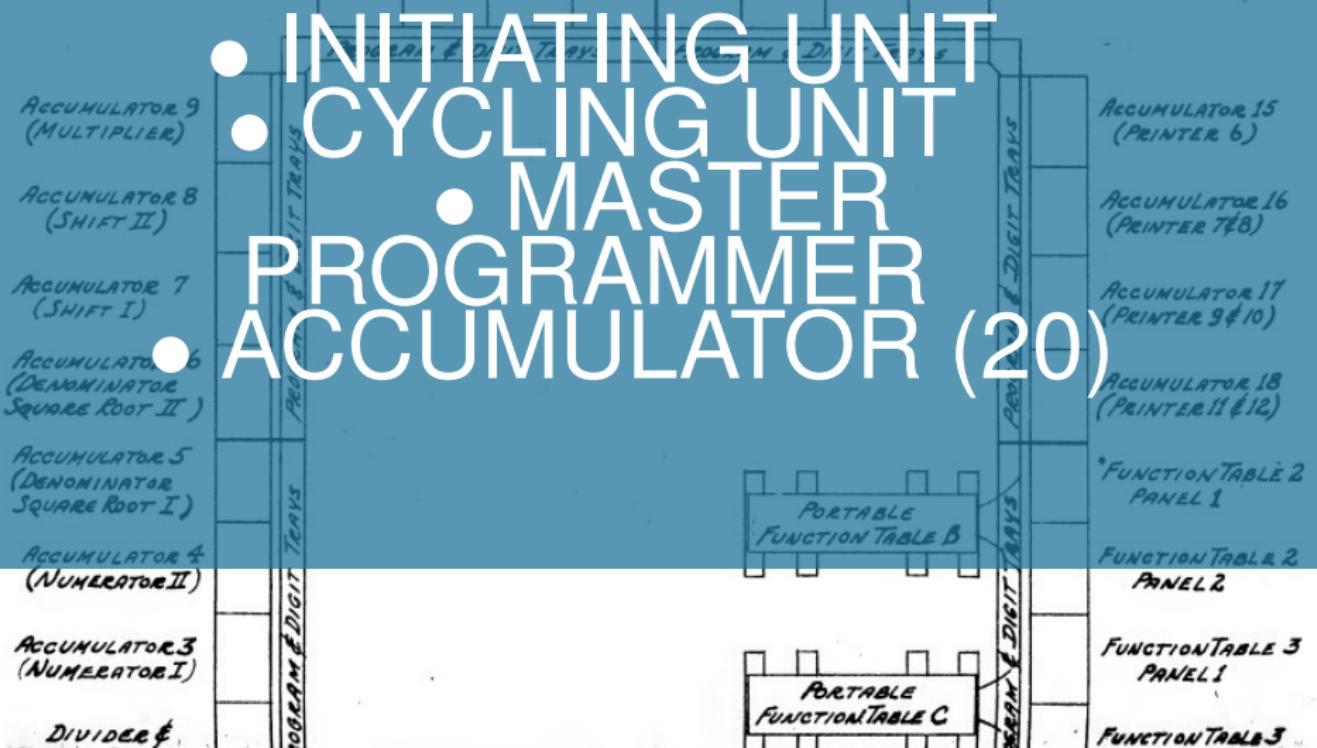
\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2





# • DIVIDER/SQUARE ROOTER - 35 PER SECOND

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER

PROGRAM 5-DIGIT TRAYS

ACCUMULATOR 10  
(MULTIPLICAND)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
(LEFT HAND  
MULTIPLYING PRODUCTS)

ACCUMULATOR 12  
(RIGHT HAND  
MULTIPLYING PRODUCTS)

ACCUMULATOR 13  
(LEFT HAND  
DIVIDERS)

ACCUMULATOR 14  
(RIGHT HAND  
DIVIDERS)

ACCUMULATOR 15  
(RIGHT HAND  
PRODUCTS  
INTER 2 & 3)

ACCUMULATOR 16  
(RIGHT HAND  
PRODUCTS  
INTER 4 & 5)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

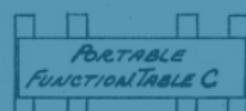
ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



# • DIVIDER/SQUARE ROOTER - 35 PER SECOND • MULTIPLIER - 357 MULTIPLICATIONS PER SECOND

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER

ACCUMULATOR 10  
(MULTIPLICAND)  
MULTIPLIER 1  
MULTIPLIER 2  
MULTIPLIER 3

ACCUMULATOR 11  
(LEFT HAND  
MULTIPLYER PRODUCTS)  
MULTIPLIER 12  
(RIGHT HAND  
MULTIPLYER PRODUCTS)  
ACCUMULATOR 13  
(RIGHT HAND  
PRODUCTS)  
ACCUMULATOR 14  
(RIGHT HAND  
PRODUCTS)  
ACCUMULATOR 15  
(RIGHT HAND  
PRODUCTS)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

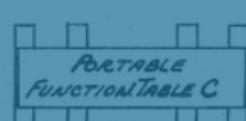
ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



• DIVIDER/SQUARE ROOTER - 35 PER SECOND

• MULTIPLIER - 357 MULTIPLICATIONS PER SECOND

• 3 MOVEABLE FUNCTION TABLES

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER

ACCUMULATOR 10  
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
(LEFT HAND  
MULTIPLYER PRODUCTS)

ACCUMULATOR 12  
(RIGHT HAND  
MULTIPLYER PRODUCTS)

ACCUMULATOR 13  
(RIGHT HAND  
PRODUCTS)

ACCUMULATOR 14  
(LEFT HAND  
PRODUCTS)

ACCUMULATOR 15  
(RIGHT HAND  
PRODUCTS)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2

PORTABLE  
FUNCTION TABLE B

PORTABLE  
FUNCTION TABLE C

• DIVIDER/SQUARE ROOTER - 35 PER SECOND

• MULTIPLIER - 357 MULTIPLICATIONS PER SECOND

• 3 MOVEABLE FUNCTION TABLES

• CARD READER

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER

ACCUMULATOR 10  
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
(LEFT HAND  
MULTIPLYER PRODUCTS)

ACCUMULATOR 12  
(RIGHT HAND  
MULTIPLYER PRODUCTS)

ACCUMULATOR 13  
(LEFT HAND  
DIVIDERS INTEG 2 & 3)

ACCUMULATOR 14  
(RIGHT HAND  
DIVIDERS INTEG 4 & 5)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

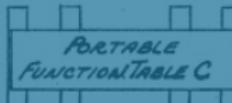
ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



- DIVIDER/SQUARE ROOTER - 35 PER SECOND
- MULTIPLIER - 357 MULTIPLICATIONS PER SECOND
- 3 MOVEABLE FUNCTION TABLES
- CARD READER
- CARD PUNCH

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER &

ACCUMULATOR 10  
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
(LEFT HAND  
MULTIPLYER PRODUCTS)

ACCUMULATOR 12  
(RIGHT HAND  
MULTIPLYER PRODUCTS)

ACCUMULATOR 13  
(LEFT HAND  
DIVIDERS INTEG 2 & 3)

ACCUMULATOR 14  
(RIGHT HAND  
DIVIDERS INTEG 4 & 5)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

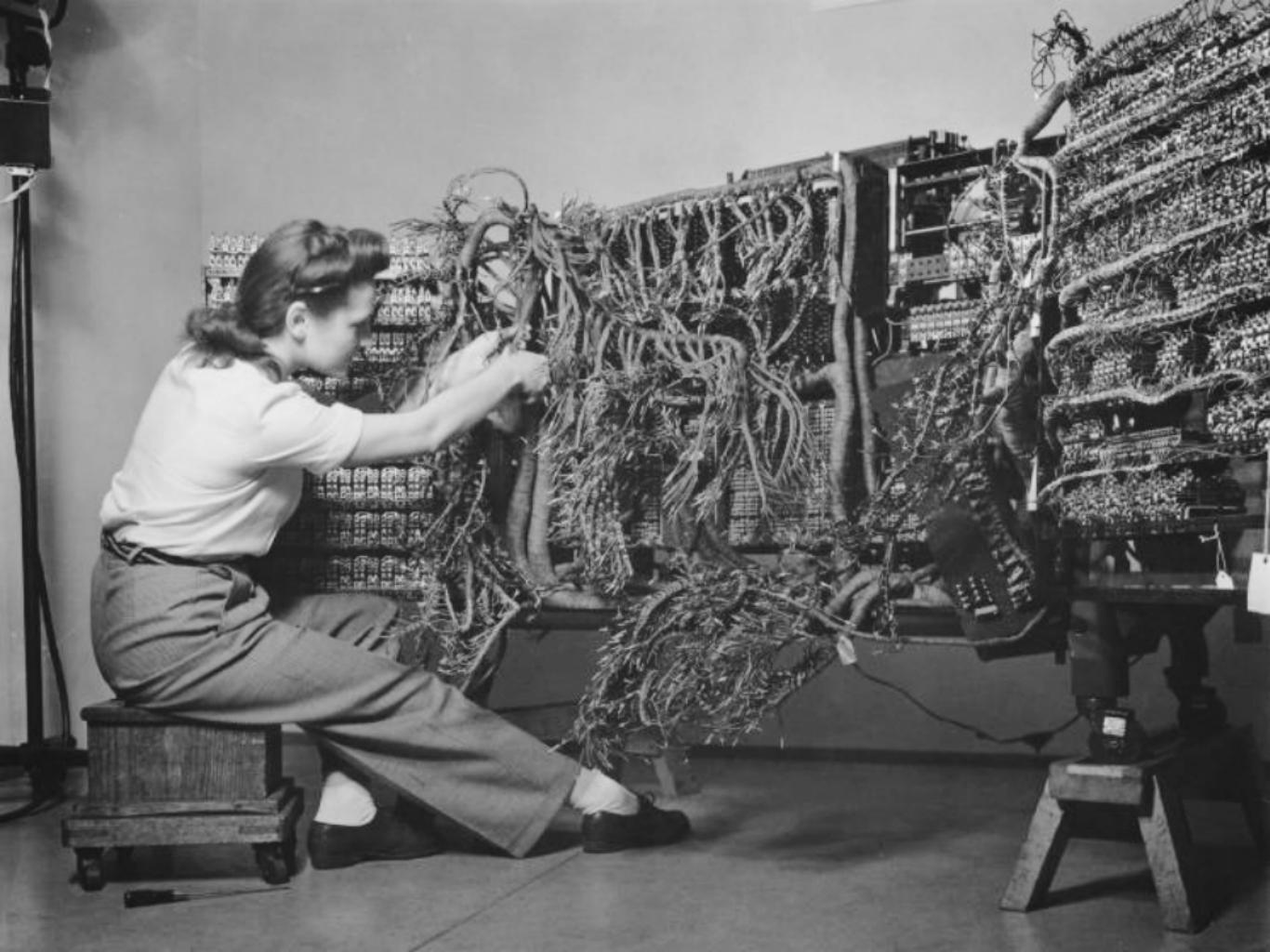
FUNCTION TABLE 3  
PANEL 2

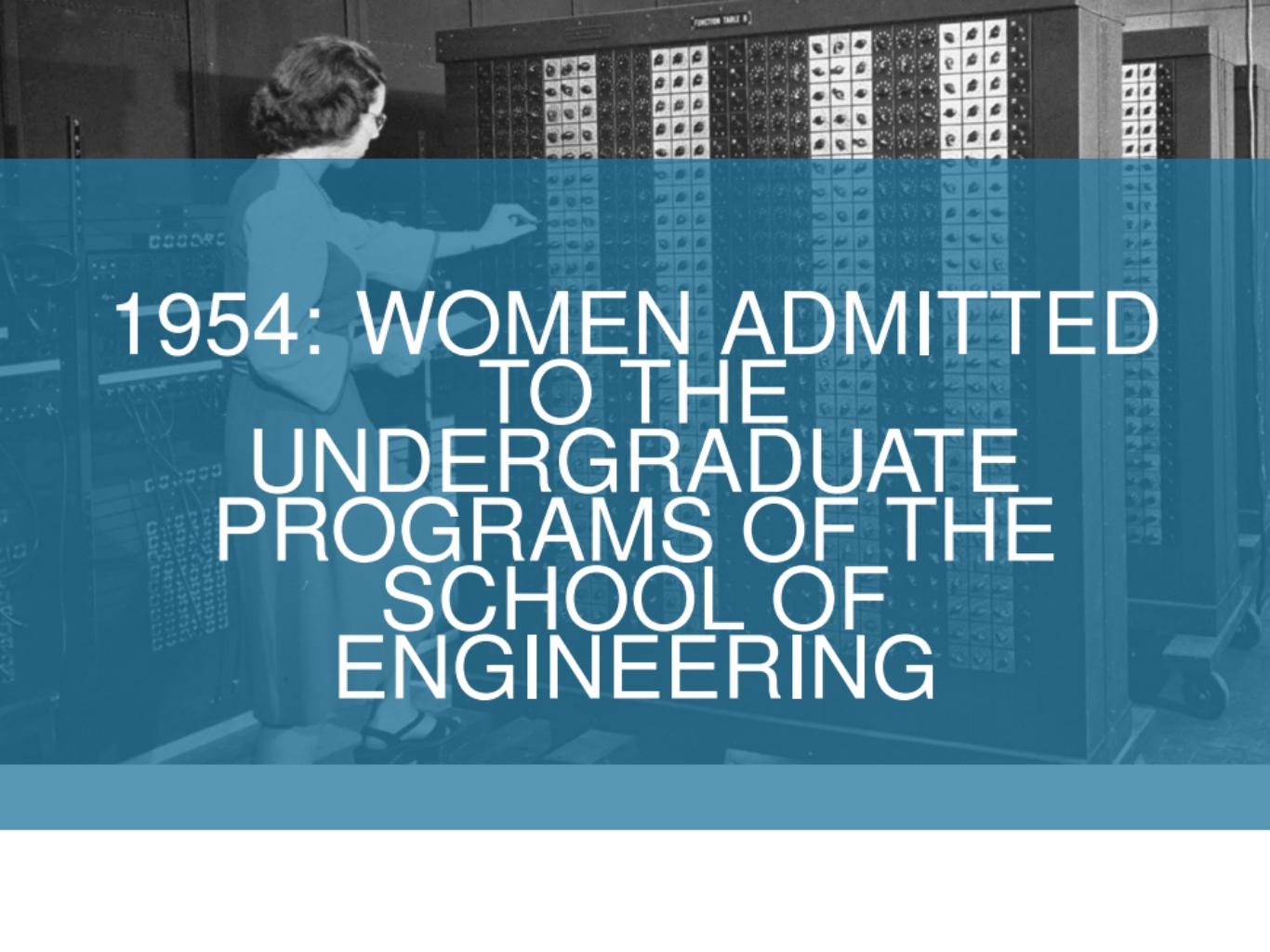
PORTABLE  
FUNCTION TABLE C

- 
- Robert F. Shaw (function tables)
  - Jeffrey Chuan Chu (divider/square-rooter)
    - Thomas Kite Sharpless (master programmer)
  - Frank Mural (master programmer)
    - Arthur Burks (multiplier)
    - Harry Huskey (reader/printer)
    - Jack Davis (accumulators)



# WIREMEN



A black and white photograph showing a woman from the side, wearing a light-colored dress, operating a large-scale control panel. The panel is filled with a grid of numerous knobs and switches. The words "FUNCTION TABLE" are visible at the top of the panel. The background shows more of the complex machinery of the computer.

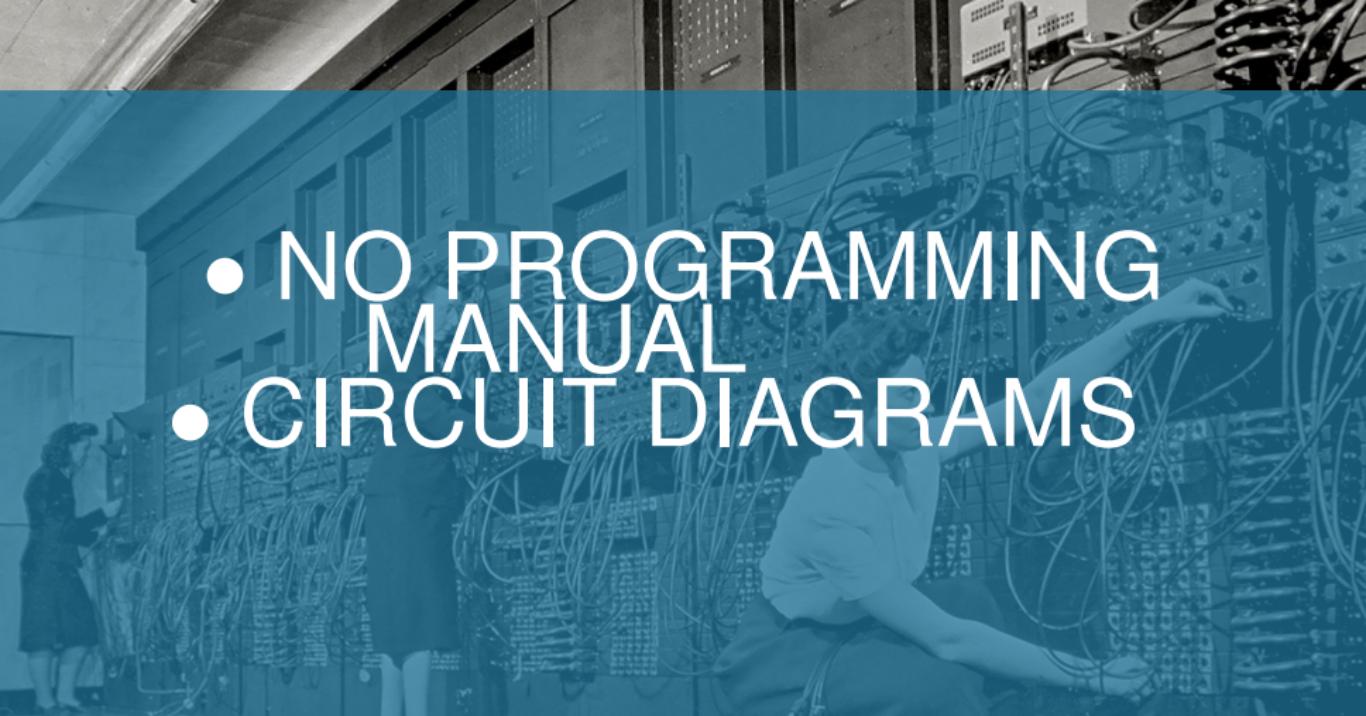
1954: WOMEN ADMITTED  
TO THE  
UNDERGRADUATE  
PROGRAMS OF THE  
SCHOOL OF  
ENGINEERING



# COMPUTERS



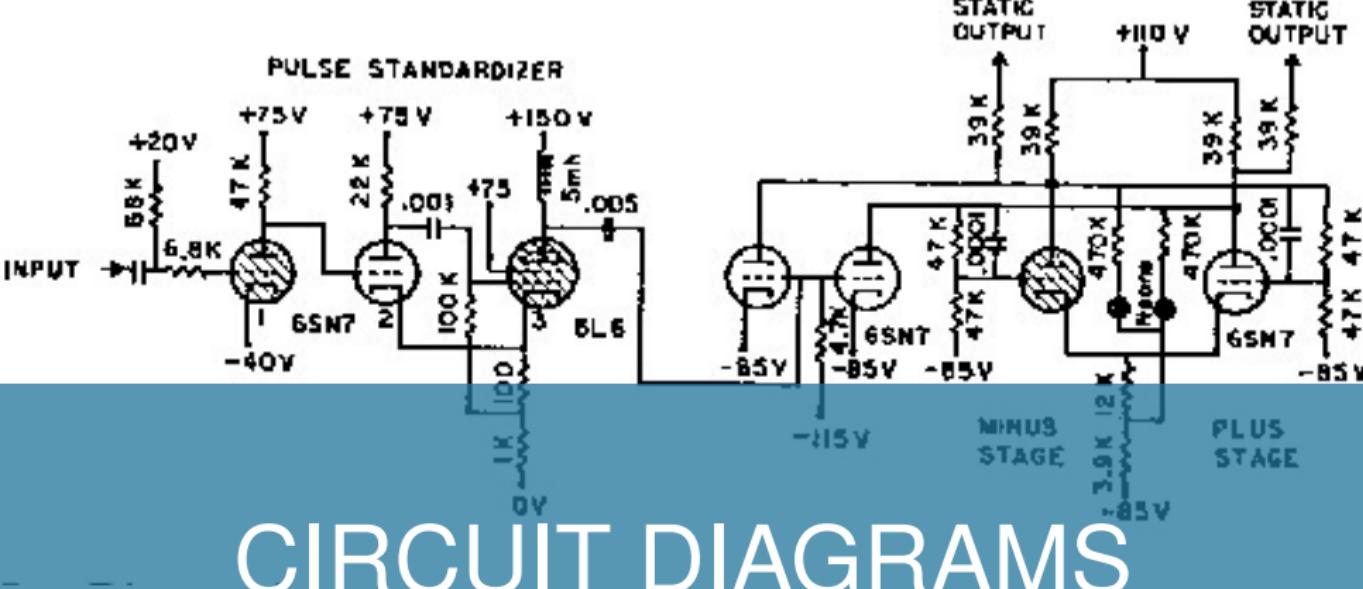
• NO PROGRAMMING  
MANUAL

- 
- NO PROGRAMMING
  - MANUAL
  - CIRCUIT DIAGRAMS

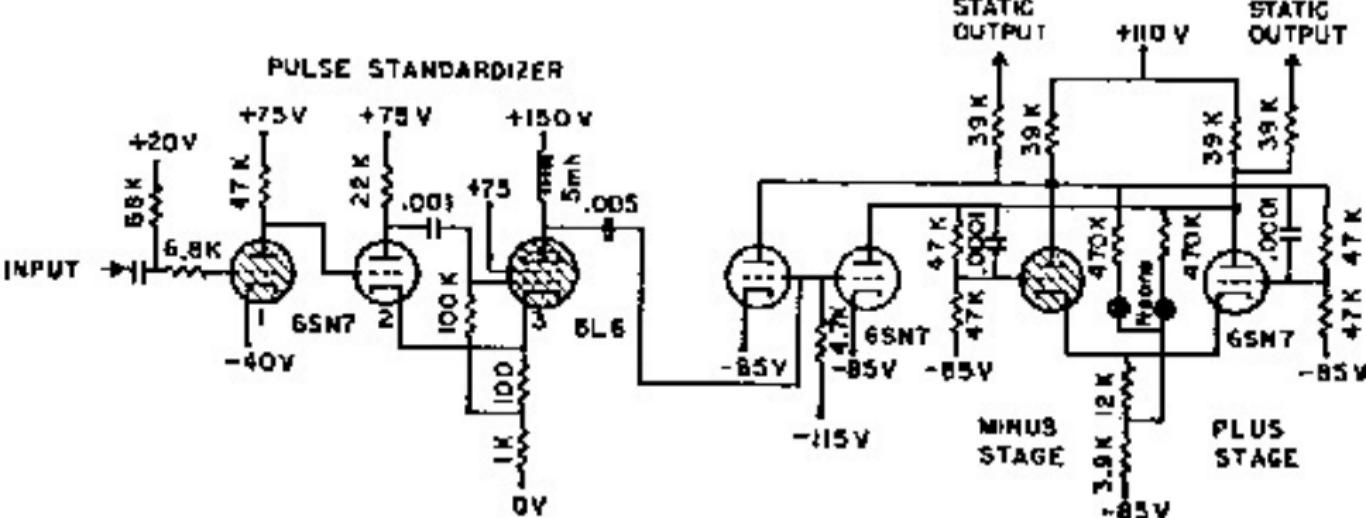
- 
- NO PROGRAMMING  
MANUAL
  - CIRCUIT DIAGRAMS
  - LOGIC DIAGRAMS

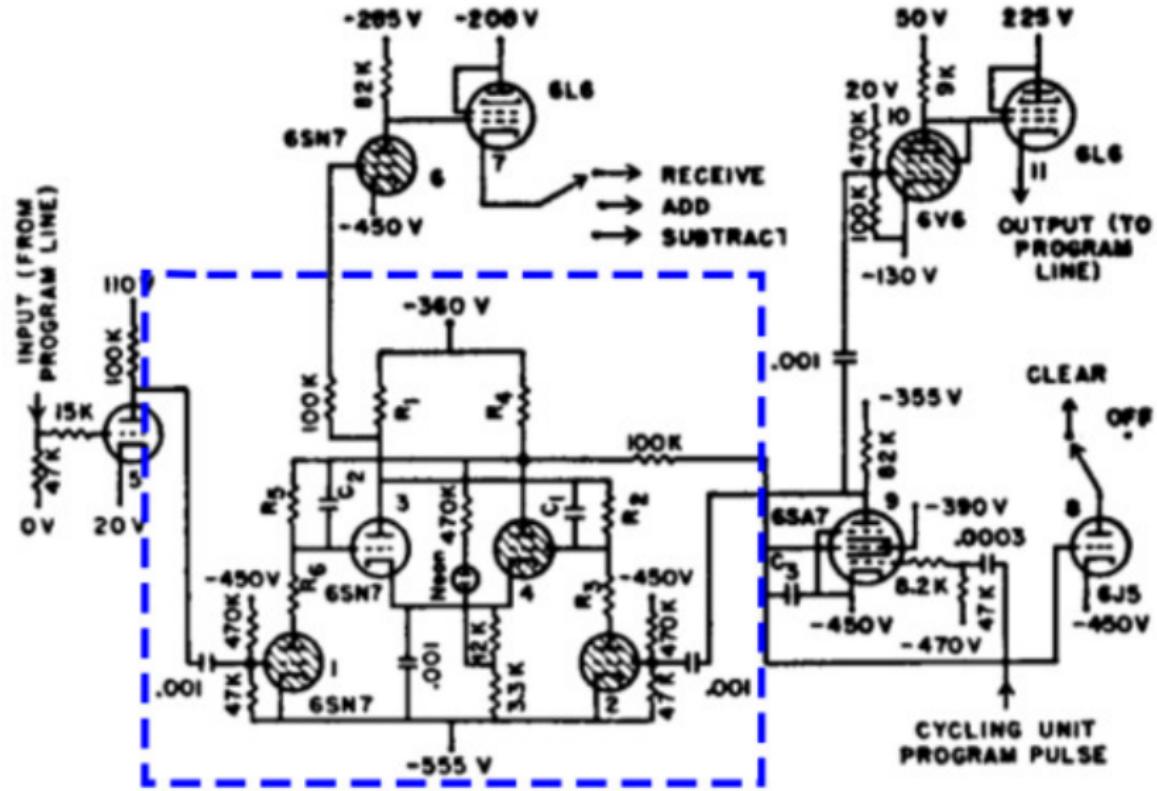
- NO PROGRAMMING  
MANUAL
- CIRCUIT DIAGRAMS
- LOGIC DIAGRAMS
- FRONT PANEL  
DIAGRAMS

- NO PROGRAMMING  
MANUAL
- CIRCUIT DIAGRAMS
- LOGIC DIAGRAMS
  - FRONT PANEL  
DIAGRAMS
- PAIRED TEACHING



# CIRCUIT DIAGRAMS





## MULTIPLICATION TABLE

MULTIPLIER  
ACCUMULATOR  
STATIC OUTPUTS:

TENS      UNITS

TENS (LEFT-HAND)

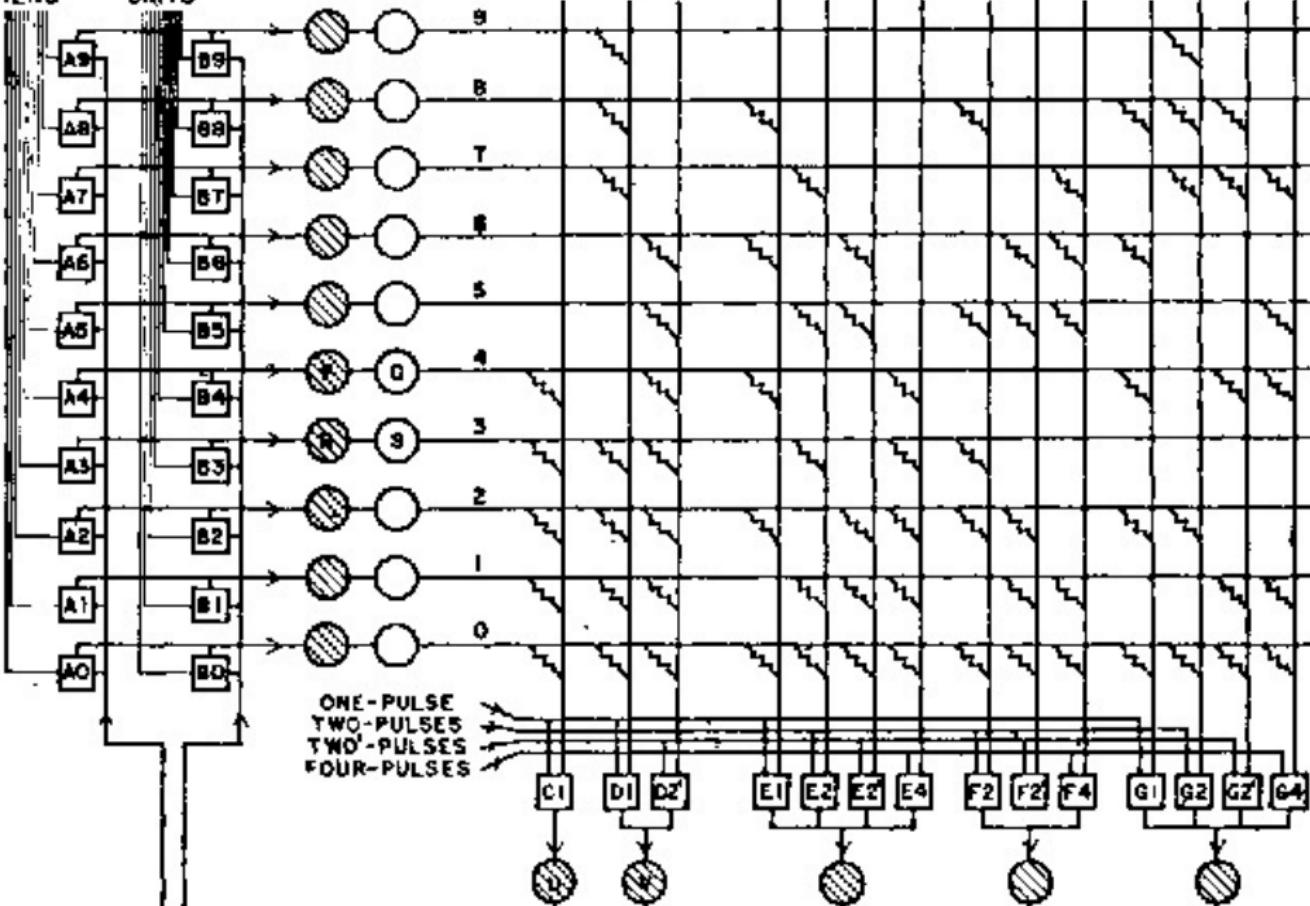
TWO    THREE

UNITS (RIGHT-HAND)

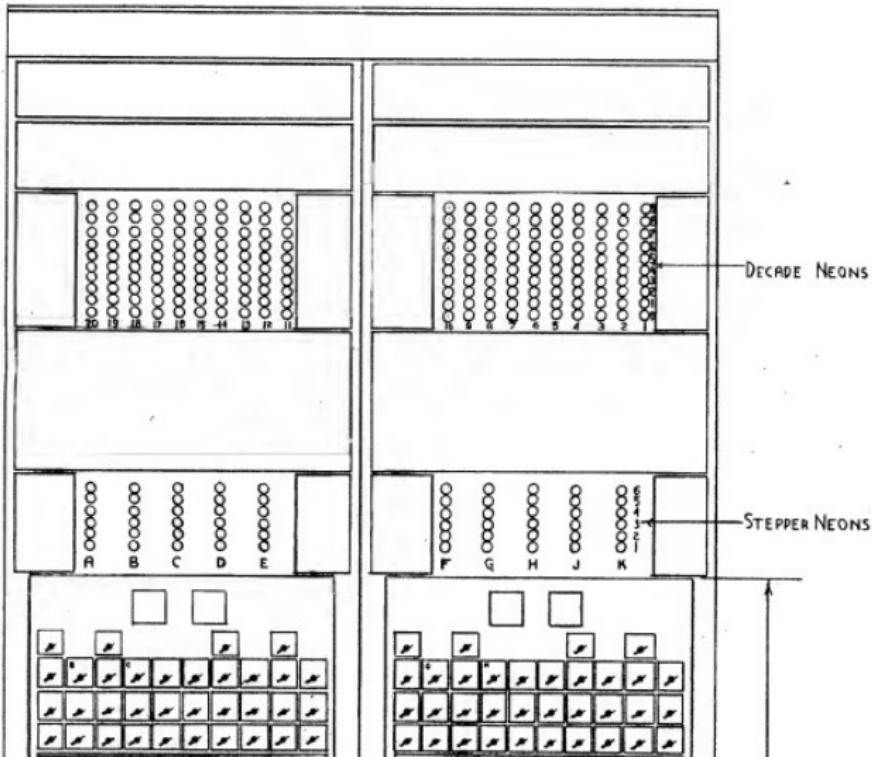
ONE

TWO

THREE



144



# ● PROGRAMMED WITH WIRES AND SWITCHES

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4

PROGRAM 6-DIGIT TRAPS

ACCUMULATOR 10  
(MULTIPLIER AND)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
LEFT HAND  
MULTIPLY PRODUCTS

ACCUMULATOR 12  
LEFT HAND  
MULTIPLY PRODUCTS

ACCUMULATOR 13  
RIGHT HAND  
MULTIPLY PRODUCTS

ACCUMULATOR 14  
RIGHT HAND  
MULTIPLY PRODUCTS

ACCUMULATOR 15  
RIGHT HAND  
MULTIPLY PRODUCTS

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

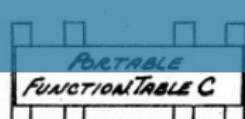
ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3



# • PROGRAMMED WITH WIRES AND SWITCHES • ACCUMULATORS ARE THE ONLY MEMORY

ACCUMULATOR 9  
(MULTIPLIER I)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4

ACCUMULATOR 10  
(MULTIPLIER II)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
LEFT HAND  
TOTAL PRODUCTS I

ACCUMULATOR 12  
LEFT HAND  
TOTAL PRODUCTS II

ACCUMULATOR 13  
RIGHT HAND  
TOTAL PRODUCTS III

ACCUMULATOR 14  
RIGHT HAND  
TOTAL PRODUCTS IV

ACCUMULATOR 15  
RIGHT HAND  
TOTAL PRODUCTS V

ACCUMULATOR 16  
RIGHT HAND  
TOTAL PRODUCTS VI

ACCUMULATOR 17  
RIGHT HAND  
TOTAL PRODUCTS VII

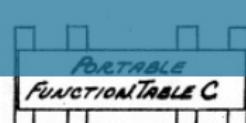
ACCUMULATOR 18  
RIGHT HAND  
TOTAL PRODUCTS VIII

ACCUMULATOR 19  
RIGHT HAND  
TOTAL PRODUCTS IX

ACCUMULATOR 20  
RIGHT HAND  
TOTAL PRODUCTS X

PROGRAM 3-DIGIT TEAMS

PROGRAM 4-DIGIT TEAMS



ACCUMULATOR 15  
(QUOTIENT 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2

● PROGRAMMED WITH WIRES AND SWITCHES  
● ACCUMULATORS ARE THE ONLY MEMORY  
● NO SEPARATION BETWEEN STORAGE AND COMPUTATION

ACCUMULATOR 9  
(MULTIPLIER I)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER \$

ACCUMULATOR 10  
(MULTIPLIER II)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
LEFT HAND  
TOTAL PRODUCTS I)

ACCUMULATOR 12  
LEFT HAND  
TOTAL PRODUCTS II)

ACCUMULATOR 13  
RIGHT HAND  
TOTAL PRODUCTS III)

ACCUMULATOR 14  
RIGHT HAND  
TOTAL PRODUCTS IV)

ACCUMULATOR 15  
RIGHT HAND  
TOTAL PRODUCTS V)

ACCUMULATOR 16  
RIGHT HAND  
TOTAL PRODUCTS VI)

ACCUMULATOR 17  
RIGHT HAND  
TOTAL PRODUCTS VII)

ACCUMULATOR 18  
RIGHT HAND  
TOTAL PRODUCTS VIII)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

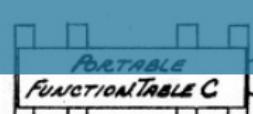
ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



- PROGRAMMED WITH WIRES AND SWITCHES
- ACCUMULATORS ARE THE ONLY MEMORY
- NO SEPARATION BETWEEN STORAGE AND COMPUTATION
- PARALLEL

ACCUMULATOR 9  
(MULTIPLIER I)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4

ACCUMULATOR 10  
(MULTIPLIER II)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
LEFT HAND  
MULTIPLYER PRODUCTS I)

ACCUMULATOR 12  
LEFT HAND  
MULTIPLYER PRODUCTS II)

ACCUMULATOR 13  
RIGHT HAND  
MULTIPLYER PRODUCTS III)

ACCUMULATOR 14  
RIGHT HAND  
MULTIPLYER PRODUCTS IV)

ACCUMULATOR 15  
RIGHT HAND  
MULTIPLYER PRODUCTS V)

ACCUMULATOR 16  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



## 2.2. TESTING AN ACCUMULATOR

Cards should be prepared as follows:

1. P 11111 11111

2. P 00000 00001

The numbers should be so placed on a card that one group in the constant transmitter, say  $A_{LR}$ , corresponds to these numbers. Next, a master programmer stepper should be used to transmit the first number into the accumulators which are to be tested eighteen times. At this time the accumulators should read

# DEBUGGING AND BREAKPOINTS

and all stages of each decade have been checked as well as the delayed carry-over circuits. Now the stepper (used above) should cause the reader to read the next card and the number to be transmitted to the accumulators twice. This should

## 2.2. TESTING AN ACCUMULATOR

Cards should be prepared as follows:

1. P 11111 11111

2. P 00000 00001 :

The numbers should be so placed on a card that one group in the constant transmitter, say  $A_{LR}$ , corresponds to these numbers. Next, a **master programmer** stepper should be used to transmit the first number into the accumulators which are to be tested eighteen times. At this time the accumulators should read

M 99999 99998

and all stages of each decade have been checked as well as the delayed carry-over circuits. Now the stepper (used above) should cause the reader to read the next card and the number to be transmitted to the accumulators twice. This should

### 2.3. TESTING THE MULTIPLIER

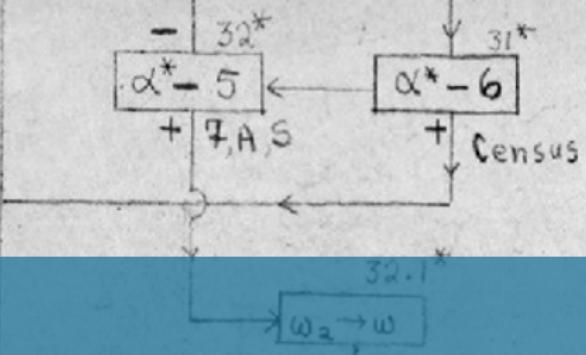
The following set of cards should be prepared.

<u>Card</u>	<u>Multiplier</u> $A_{LR}$ (say)	<u>Multiplicand</u> $B_{LR}$ (say)
1	P 00000 00000	P 11111 11111
2	P 11111 11111	P 11111 11111
3	P 11111 11111	P 22222 22222
.....	.....	.....
10	P 11111 11111	P 99999 99999
11	P 22222 22222	P 11111 11111
12	P 22222 22222	P 22222 22222
.....	.....	.....
82	P 99999 99999	P 99999 99999
83	F P 11111 11111	M 11111 11111
84	M 11111 11111	P 11111 11111
85	M 11111 11111	M 11111 11111

2.3. TESTING THE MULTIPLIER

The following set of cards should be prepared.

<u>Card</u>	<u>Multiplier</u> $A_{LR}$ (say)	<u>Multiplicand</u> $B_{LR}$ (say)
1	P 00000 00000	P 11111 11111
2	P 11111 11111	P 11111 11111
3	P 11111 11111	P 22222 22222
.....	.....	.....
10	P 11111 11111	P 99999 99999
11	P 22222 22222	P 11111 11111
12	P 22222 22222	P 22222 22222
.....	.....	.....
82	P 99999 99999	P 99999 99999
83	P 11111 11111	M 11111 11111
84	M 11111 11111	P 11111 11111
85	M 11111 11111	M 11111 11111



$$10^{-3} \left[ d_1 - \right.$$

$$10^{-5} (T_{\text{eff}} +$$

16

$$10^{-1}Q = 10^{-1}(Q + \int_0^b S_o(h))$$

$$10^{-1}Q_1 = 10^{-1}(Q + \int_{\text{h}}^{\text{b}} S_o(\text{h}))$$

ES

$$M = 10^4 (g + f \cdot s_i(h))$$

$10^{-1} g$  +  
- IS

23

23

$$0 \rightarrow 10 \text{ b to } 9$$

$$\xi(10, 9, 8) \rightarrow 4(3, 2, 1)$$

$$10^{-1}g = -10^{-1}\xi(7, 6) \sum$$

$$10^{-1}g \rightarrow 10$$

fif

$$\begin{aligned}\xi_0 &= \xi_0(m_0 - \zeta) \\ \xi_1 &= \xi_1(\zeta - 1) \\ \overline{\xi_0 \xi_1} &= \xi_0(10^{-5} \overline{\xi_1}) \\ \overline{\xi_0^2} &= \text{diag}(\zeta - 1) \\ &\quad \text{of } \overline{\xi_0^2} \\ \overline{\xi_1^2} &= \text{diag}(10^{-6}) \\ &\quad \text{of } (10^{-5} \overline{\xi_1})^2 \\ \xi' &= 10^{-5} \overline{\xi_0^2} + 2 \overline{\xi_0 \xi_1} \\ &\quad + 10^{-5} \overline{\xi_1^2} \\ \xi' &\rightarrow \xi \text{ to 16}\end{aligned}$$

# SIMULATION OF THE HYDROGEN BOMB

**x** = distance down range

**y** = altitude

**z** = distance cross range in the right hand

**sense**

# BALLISTICS PROGRAM VARIABLES

**w<sub>x</sub>** = wind down range

**w<sub>z</sub>** = wind across range

**Ω** = angular velocity of the earth

**L** = latitude

**a** = azimuth

**E** =  $a(y)H(y)G\left(\frac{v}{a(y)}\right)$

$x$  = distance down range

$y$  = altitude

$z$  = distance cross range in the right hand  
sense

$w_x$  = wind down range

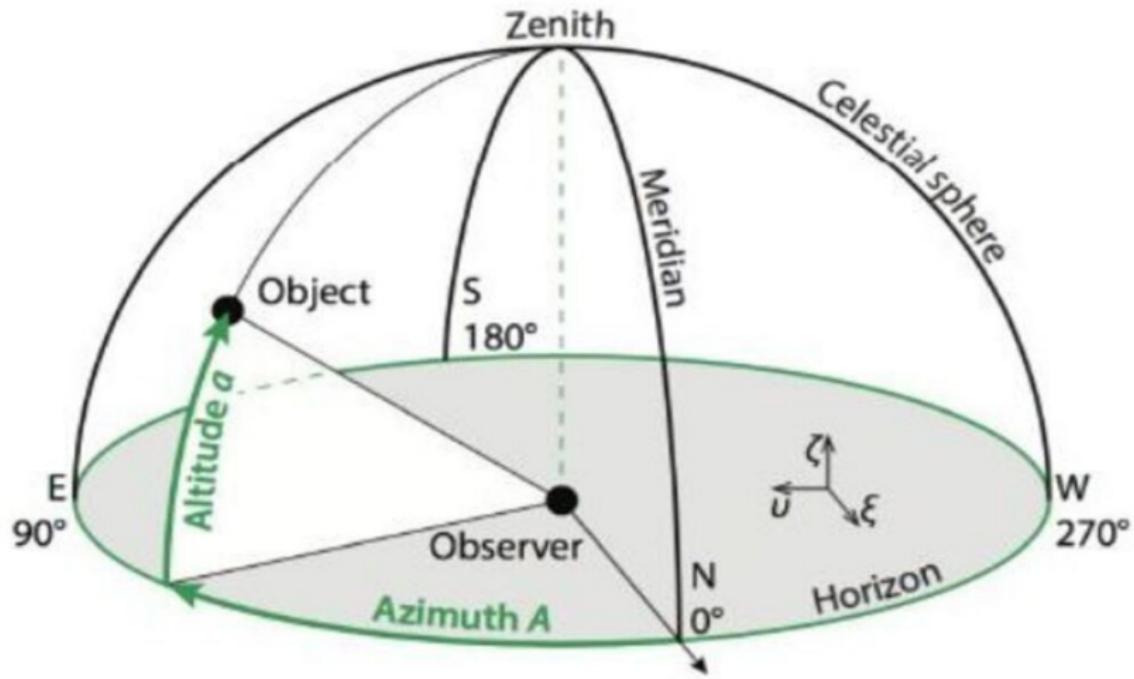
$w_z$  = wind across range

$\Omega$  = angular velocity of the earth

$L$  = latitude

$\alpha$  = azimuth

$E = a(y)H(y)G\left(-\frac{v}{a(y)}\right)$



The equations for particle trajectory theory are:

$$x' = -E(x' - w_x) + 2 \Omega \cos L \sin a y'$$

$$y' = -E y' - g - 2 \Omega \cos L \sin a x'$$

$$z' = -E(z' - w_z) + 2 \Omega \sin L x' + 2 \Omega \cos L \cos a y'$$

# BALLISTICS PROGRAM

## EQUATIONS

where

$$x' = \frac{dx}{dt}$$

The equations for particle trajectory theory are:

$$x' = -E(x' - w_x) + 2 \Omega \cos L \sin \alpha y'$$

$$y' = -E y' - g - 2 \Omega \cos L \sin \alpha x'$$

$$z' = -E(z' - w_z) + 2 \Omega \sin L x' + 2 \Omega \cos L \cos \alpha y'$$

where

$$x' = \frac{dx}{dt}$$



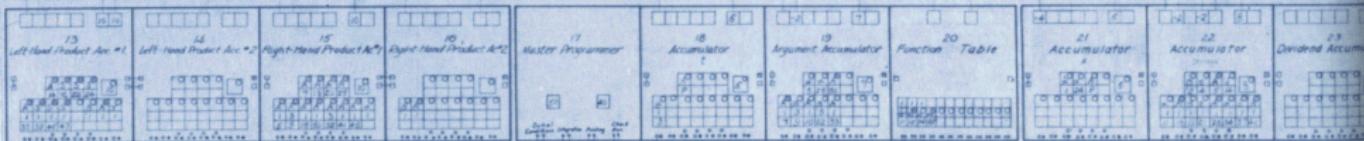
# PIANO PEDALING SHEET



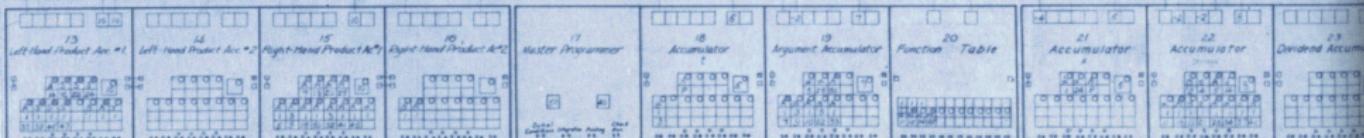
^ ^ ^ ^ ^



^ ^ ^ ^ ^



# PEDALING SHEET



# NUCLEAR BOMB SIMULATION

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4

PROGRAM 6 DIGIT TRAYS

ACCUMULATOR 10  
(MULTIPLICAND)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
(LEFT HAND  
MULTIPRODUCT)

ACCUMULATOR 12  
(LEFT HAND  
MULTIPRODUCTS II)

ACCUMULATOR 13  
(LEFT HAND  
MULTIPRODUCTS III)

ACCUMULATOR 14  
(RIGHT HAND  
MULTIPRODUCTS)

ACCUMULATOR 15  
(RIGHT HAND  
MULTIPRODUCTS IV)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

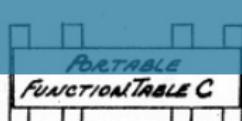
ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



# • NUCLEAR BOMB SIMULATION

# • BALLISTICS TRAJECTORY CALULATIONS

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER

ACCUMULATOR 10  
(MULTIPLICAND)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

CUMULATOR 11  
(LEFT HAND  
MULTI PRODUCTS)

CUMULATOR 12  
(LEFT HAND  
MULTI PRODUCTS)

CUMULATOR 13  
(LEFT HAND  
MULTI PRODUCTS)

CUMULATOR 14  
(RIGHT HAND  
MULTI PRODUCTS)

CUMULATOR 15  
(RIGHT HAND  
MULTI PRODUCTS)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

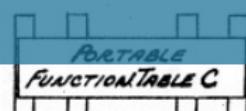
ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



# • NUCLEAR BOMB SIMULATION

## • BALLISTICS TRAJECTORY CALULATIONS

## • ELECTION PREDICTION

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4

ACCUMULATOR 10  
(MULTIPLICAND)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

SUMULATOR I  
(LEFT HAND  
MULTI PRODUCTS)

SUMULATOR II  
(RIGHT HAND  
MULTI PRODUCTS)

SUMULATOR III  
(LEFT HAND  
FINAL PRODUCTS)

SUMULATOR IV  
(RIGHT HAND  
FINAL PRODUCTS)

SUMULATOR V  
(LEFT HAND  
SECOND PRODUCTS)

SUMULATOR VI  
(RIGHT HAND  
SECOND PRODUCTS)

SUMULATOR VII  
(LEFT HAND  
THIRD PRODUCTS)

SUMULATOR VIII  
(RIGHT HAND  
THIRD PRODUCTS)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 2&3)

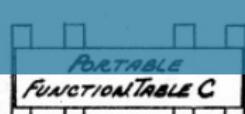
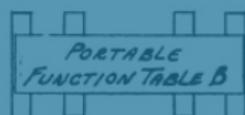
ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



# NUCLEAR BOMB SIMULATION

## BALLISTICS TRAJECTORY CALULATIONS

## ELECTION PREDICTION

## WEATHER FORECASTING

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4

ACCUMULATOR 10  
(MULTIPLICAND)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

SUMULATOR I  
(LEFT HAND  
MULTI PRODUCTS)

SUMULATOR II  
(LEFT HAND  
MULTI PRODUCTS)

SUMULATOR III  
(LEFT HAND  
MULTI PRODUCTS)

SUMULATOR IV  
(RIGHT HAND  
MULTI PRODUCTS)

SUMULATOR V  
(RIGHT HAND  
MULTI PRODUCTS)

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 2&3)

ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

PORTABLE  
FUNCTION TABLE C

FUNCTION TABLE 3  
PANEL 3

# ● COMPRESSIBLE LAMINAR BOUNDARY LAYER FLOW

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER

PROGRAM 8-DIGIT TRAYS

ACCUMULATOR 10  
(MULTIPLIER AND)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
LEFT HAND  
PARTIAL PRODUCTS

ACCUMULATOR 12  
RIGHT HAND

ACCUMULATOR 13  
RIGHT HAND  
PARTIAL PRODUCTS

ACCUMULATOR 14  
RIGHT HAND BASES

ACCUMULATOR 15  
RIGHT HAND  
PRINTERS 2 & 3

ACCUMULATOR 16  
RIGHT HAND  
PRINTERS 4 & 5

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



# • COMPRESSIBLE LAMINAR BOUNDARY LAYER FLOW • ZERO-PRESSURE PROPERTIES OF DIATOMIC GASES

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4

ACCUMULATOR 10  
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
RIGHT HAND  
PARTIAL PRODUCTS I

ACCUMULATOR 12  
RIGHT HAND  
PARTIAL PRODUCTS II

ACCUMULATOR 13  
RIGHT HAND  
PARTIAL PRODUCTS III

ACCUMULATOR 14  
RIGHT HAND  
PARTIAL PRODUCTS IV

ACCUMULATOR 15  
RIGHT HAND  
PARTIAL PRODUCTS V

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

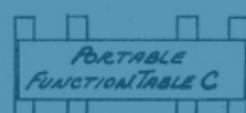
ACCUMULATOR 18  
(PRINTER 11&12)

\*FUNCTION TABLE 2  
PANEL 1

FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

FUNCTION TABLE 3  
PANEL 2



# • COMPRESSIBLE LAMINAR BOUNDARY LAYER FLOW

## • ZERO-PRESSURE PROPERTIES OF DIATOMIC GASES

## • REFLECTION AND REFRACTION OF PLANE SHOCK WAVES

ACCUMULATOR 9  
(MULTIPLIER)

ACCUMULATOR 8  
(SHIFT II)

ACCUMULATOR 7  
(SHIFT I)

ACCUMULATOR 6  
(DENOMINATOR  
SQUARE ROOT II)

ACCUMULATOR 5  
(DENOMINATOR  
SQUARE ROOT I)

ACCUMULATOR 4  
(NUMERATOR II)

ACCUMULATOR 3  
(NUMERATOR I)

DIVIDER 4

ACCUMULATOR 10  
(MULTIPLIER)

MULTIPLIER 1

MULTIPLIER 2

MULTIPLIER 3

ACCUMULATOR 11  
RIGHT HAND  
PARTIAL PRODUCTS I

ACCUMULATOR 12  
RIGHT HAND

ACCUMULATOR 13  
RIGHT HAND  
PARTIAL PRODUCTS II

ACCUMULATOR 14  
RIGHT HAND

ACCUMULATOR 15  
RIGHT HAND  
PARTIAL PRODUCTS III

ACCUMULATOR 16  
RIGHT HAND  
PARTIAL PRODUCTS IV

ACCUMULATOR 17  
RIGHT HAND  
PARTIAL PRODUCTS V

ACCUMULATOR 15  
(PRINTER 6)

ACCUMULATOR 16  
(PRINTER 7&8)

ACCUMULATOR 17  
(PRINTER 9&10)

ACCUMULATOR 18  
(PRINTER 11&12)

FUNCTION TABLE 2  
PANEL 1

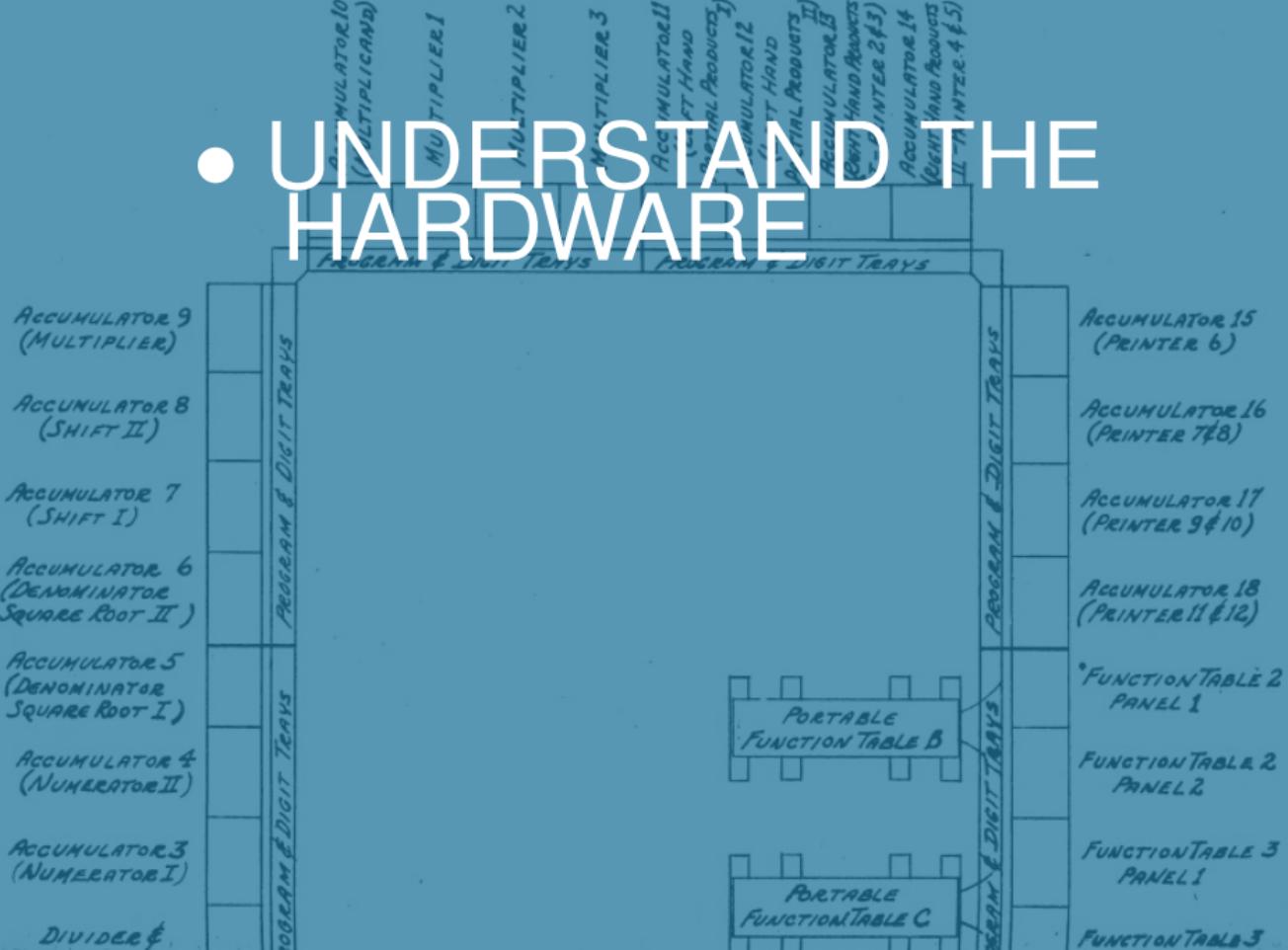
FUNCTION TABLE 2  
PANEL 2

FUNCTION TABLE 3  
PANEL 1

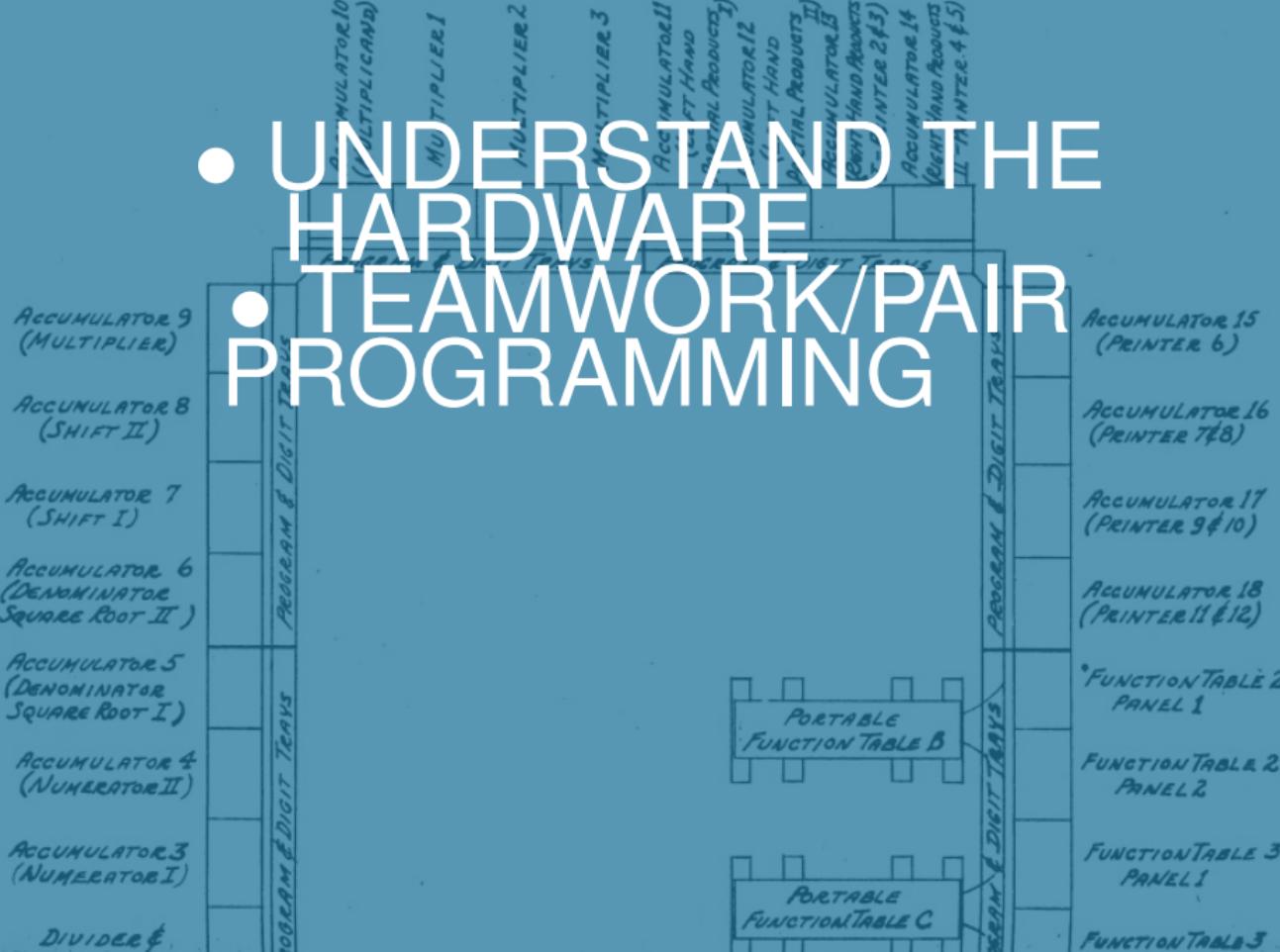
FUNCTION TABLE 3  
PANEL 2

PORTABLE  
FUNCTION TABLE C

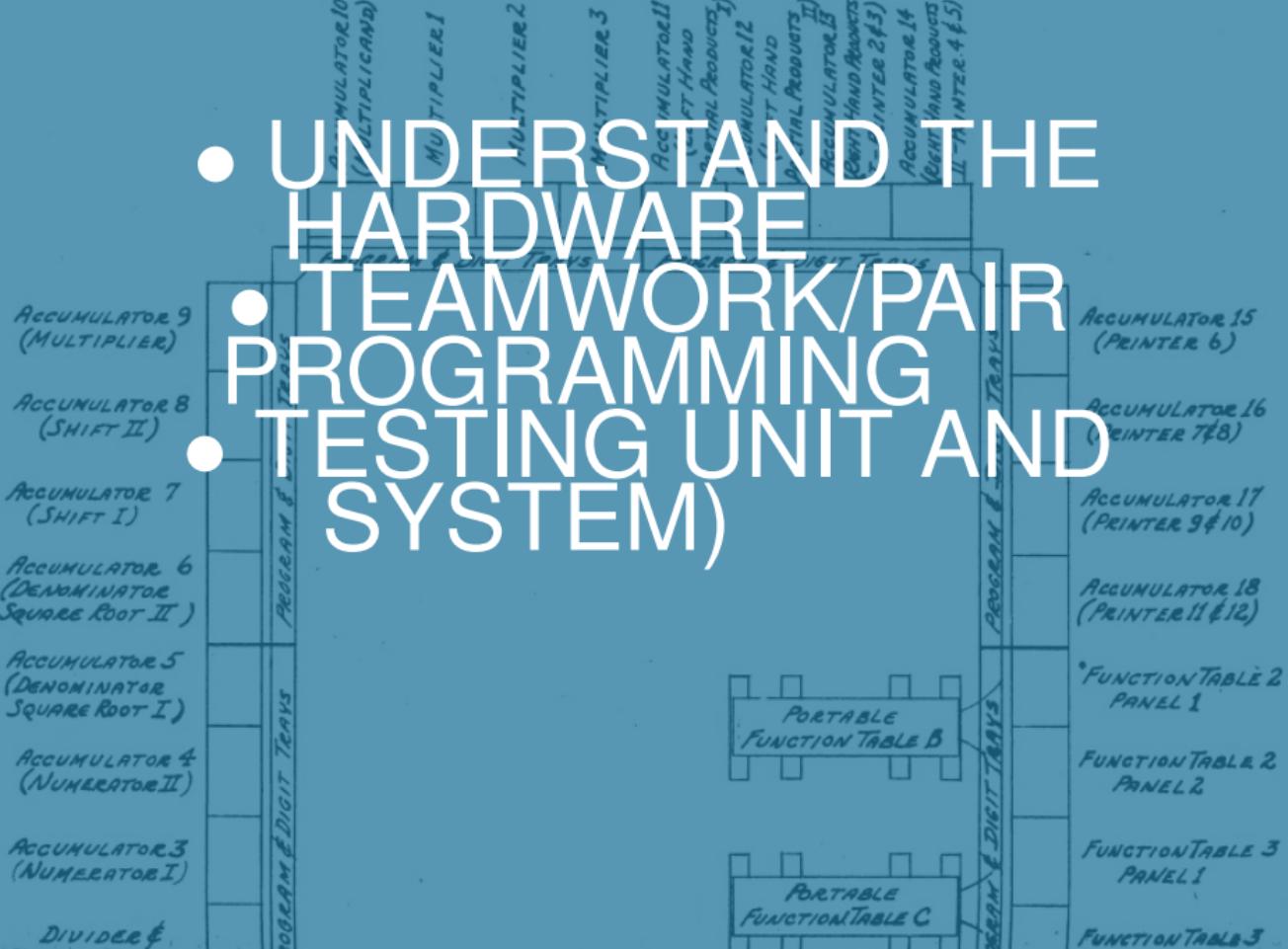
# • UNDERSTAND THE HARDWARE



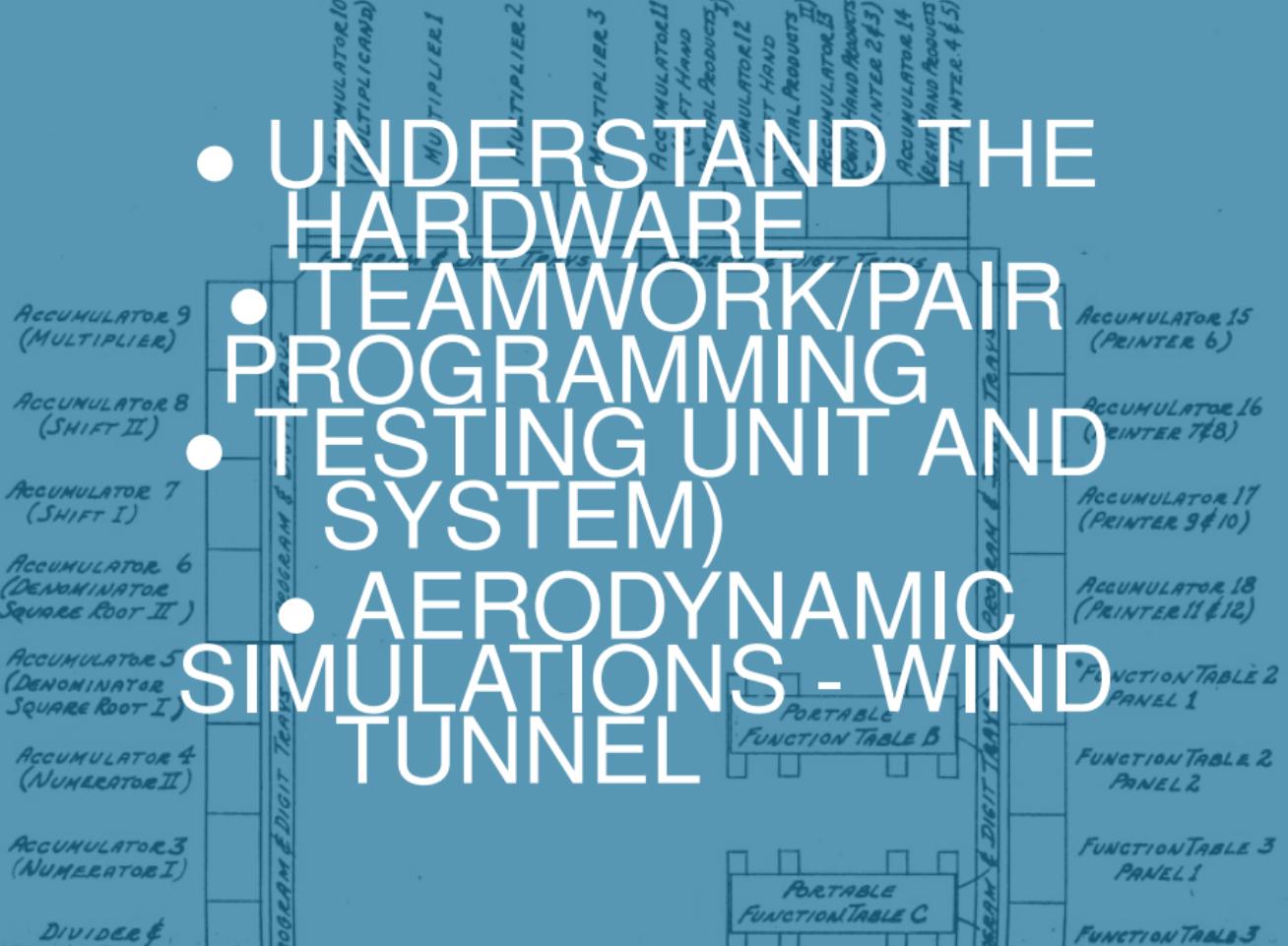
# • UNDERSTAND THE HARDWARE • TEAMWORK/PAIR PROGRAMMING



- UNDERSTAND THE HARDWARE TEAMWORK/PAIR PROGRAMMING
  - TESTING UNIT AND SYSTEM)



- UNDERSTAND THE HARDWARE
- TEAMWORK/PAIR PROGRAMMING
- TESTING UNIT AND SYSTEM)
- AERODYNAMIC SIMULATIONS - WIND TUNNEL



- UNDERSTAND THE HARDWARE
- TEAMWORK/PAIR PROGRAMMING
- TESTING UNIT AND SYSTEM)
- AERODYNAMIC SIMULATIONS - WIND TUNNEL
- PEDALING SHEETS

