

The ENIAC: The Grandfather of all Computers

Brian L. Stuart
Drexel University

The ENIAC



What Is ENIAC?

- Large-scale computing system
- Built during WWII
- Dedicated February 15, 1946
- Converted to sequential instruction execution in 1948
- Retired 1955
- Used for:
 - Atomic bomb development
 - Ballistics trajectories
 - Number theory
 - Supersonic air flow
 - Weather prediction
 - and more

Common Statistics

- 40 racks, each 8' by 2'
- About 18,000 tubes
- 100KHz basic clock
- 200 μ S addition time
- About 150KW of power

Key People



John Mauchly
Physicist



John Presper Eckert
Electrical Engineer

Key People

Herman Goldstine



Arthur Burks



Harry Huskey



Key People

- Kay Mauchly (Kathleen McNulty Mauchly Antonelli)
- Fran Bilas (Frances Bilas Spence)
- Jean Bartik (Betty Jean Jennings Bartik)
- Betty Holberton (Frances Elizabeth Snyder Holberton)
- Ruth Lichterman (Ruth Lichterman Teitelbaum)
- Marlyn Wescoff (Marlyn Wescoff Meltzer)
- Adele Goldstine (Adele Katz Goldstine)

Key People

Kay Mauchly



Fran Bilas

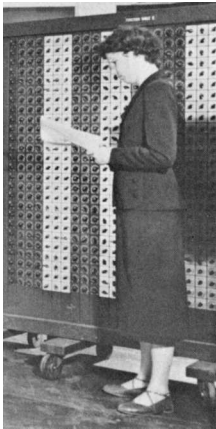


Jean Bartik

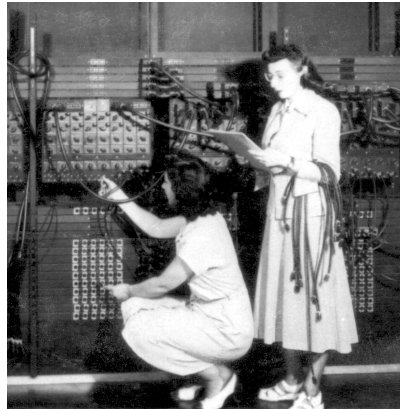


Key People

Betty Holberton



Ruth Lichterman Marlyn Wescoff



Key People



Frances Spence



Joan Barish



Marilyn Helgeson



Kathleen Antonelli



Elizabeth Holberton

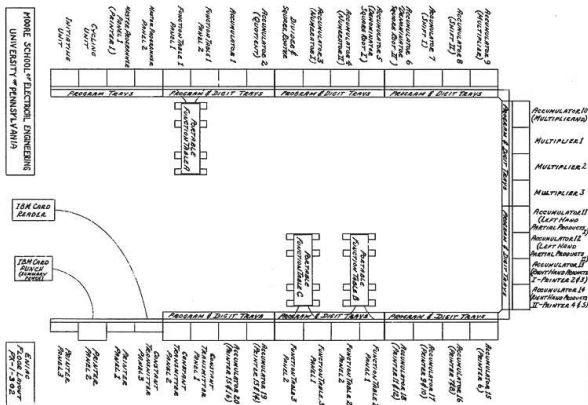


Ruth Teitelbaum

Basic Architecture

- Initiating unit
- Cycling unit
- Two-panel master programmer
- 20 Accumulator units
- Multiplying unit
- Divider/Square rooter unit
- 3 Function table units
- Constant transmitter/card reader unit
- Card punch unit

Moore School Layout



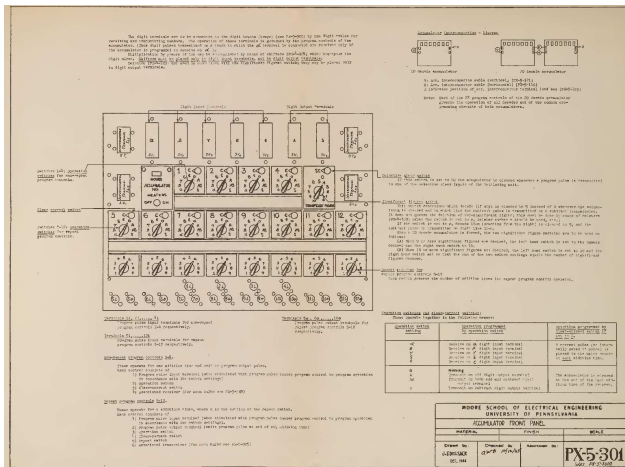
Unusual Characteristics

- No bulk writeable memory
- No separation between storage and computation
- Divider/square rooter not always exact
- Initially programmed with wires and switches
- Feels like a dataflow architecture

Accumulator

- 10 digits + sign (P or M)
- Negative numbers stores as $M + 10$ s complement
- 5 inputs: α , β , γ , δ , and ϵ
- 2 outputs: A and S
- 12 programs:
 - Operation: α , β , γ , δ , ϵ , 0, A, AS, or S
 - Clear/correct
 - Repeat count (on programs 5–12)

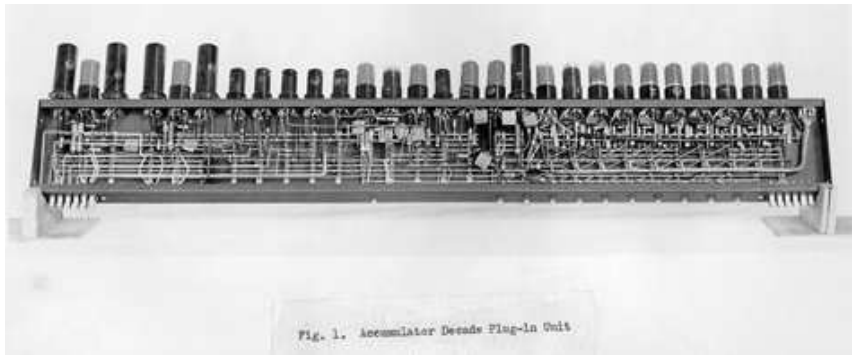
Accumulator



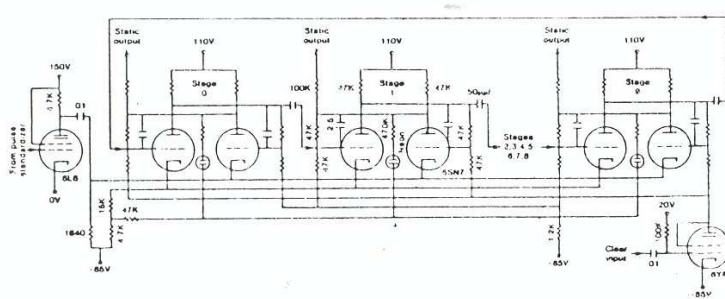
How it Works

- Add Accumulator 1 to Accumulator 2
- Accumulator 1 has 15 and Accumulator 2 has 27
- Control signal sent to both accumulators
- Accumulator 1 program sends 1 pulse on 10s line and 5 pulses on 1s line
- Accumulator 2 program receives pulses from Accumulator 1:
 - 10s digit advances to 3
 - 1s digit advances to 2 with carry flipflop set
- Carry gate propagates carry, advancing 10s digit to 4
- Accumulators emit control pulse to trigger next operation

Decade Counter Module



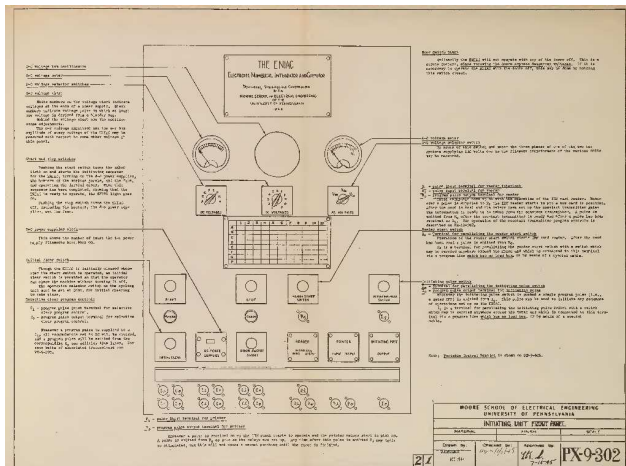
Decade Counter Schematic



Initiating Unit

- Controls power sequencing
- Provides initiating pulse
- Provides card reader interlock
- Provides card punch interlock
- Meters for checking power supply levels
- Oscilloscope for checking power supply ripple/noise

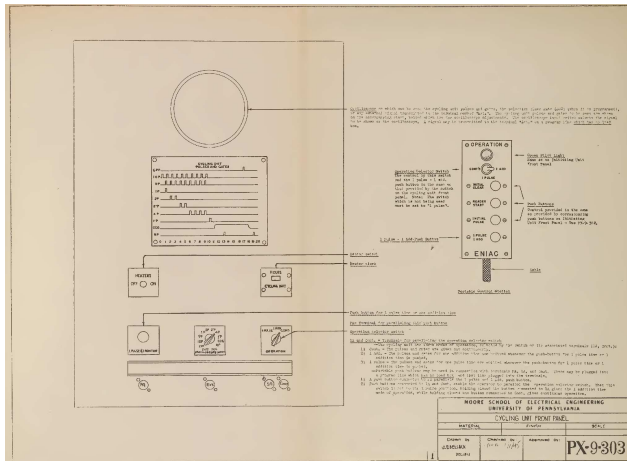
Initiating Unit



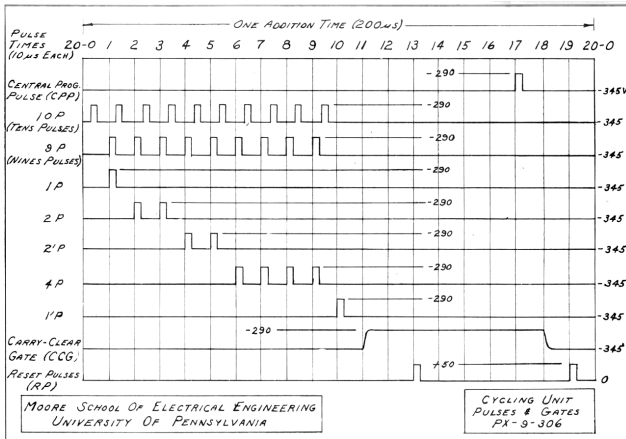
Cycling Unit

- Distributes multi-phase clock throughout system
- Oscilloscope for monitoring individual clock signals
- 100 KHz design rate
- 60 KHz for stability for sometime after move to Aberdeen
- Three clock modes:
 - Continuous
 - One add time
 - One pulse

Cycling Unit



Clock Signals



Master Programmer

- 10 6-stage counters
- 20 decade counters
- Complex nested loop structures
- Negative/non-negative conditional branching:
 - Run accumulator output sign into dummy program
 - Run program output of dummy program into stage direct input
 - Two stage program outputs trigger negative and non-negative actions

Master Programmer

- “Computed goto:”
 - Run selected digit output into stage direct input
 - Stages 1–6 program outputs trigger actions based on values 0–5 of accumulator digit

Master Programmer



REPRODUCED BY THE NATIONAL ARCHIVES AT COLLEGE PARK, MARYLAND

- [illegible]

The operation of a shopper with the associated equipment is as follows:

At the end of the 100/104, the shopper will stop at left or the left stage and wait, decide

Supplies a PROGRAM pointer to register on a debugger program's input terminal. One additional value before a program pointer is defined from the program (with program address) corresponding to the stage the debugger is on at the time it is defined and a program pointer is sent to the output device of the stage of the debugger.

...the fact that the ...
...the ...
...the ...

The larvae must take the pulps supplied to the associated streptococcal process pulp upon insertion (with a one-minute time delay) and never supplied to the dental pulp upon insertion, in order to preclude the risk that they take the pulps being supplied to a

decade from both sources simultaneously, or from a decade direct input terminal and a decade over from a previous decade simultaneously.

output [1.....M] and be set up on the device address, each output associated with the corresponding stage [1.....N] of the stagger and known with the corresponding pinout (stage terminals $\{O_1, \dots, O_M\}$). Mounted a program code is received on [2] a pinset is emitted from one of the output terminals (one addressable line label). The input is, please

deleted on Q1 are deleted from Q2; the data by prison received on Q1 are modified from Q2, etc. The last two prisons received on Q1 are modified from Q2, and the stopper and the error stated decades by 1200 PART 35 their original state, ready to repeat the process. The first instance of these operations is on 7041000.

<u>Program Point</u>	<u>Operation</u>
0	Begin program point 000 000
1	Begin program point edited (from 000,000,000)

Program Phase	Processing
0	Output program name and DED Output program name modified (from Sysname.sys)
1	Device assigned to next stage
2	For each the complete MAGNETIC the number and up to the maximum iterations, all devices disconnected with assigned ID are checked to zero and the assigned ID is changed to the next stage or (if to be in the next stage)

Re. correspondence & details from the dropped gill net gill T12 in the trapper plug-in unit, see. *Am. J. Zool.* 1994: 104-105.

THESE ARE THE RESULTS OF THE RESEARCH CONDUCTED BY THE RESEARCHER IN THE FIELD OF THE RESEARCH.

12345678910111213141516171819202122232425262728293031323334353637383940414243444546474849505152535455565758596061626364656667686970717273747576777879808182838485868788899091929394959697989910010110210310410510610710810911011111211311411511611711811912012112212312412512612712812913013113213313413513613713813914014114214314414514614714814915015115215315415515615715815916016116216316416516616716816917017117217317417517617717817918018118218318418518618718818919019119219319419519619719819920020120220320420520620720820921021121221321421521621721821922022122222322422522622722822923023123223323423523623723823924024124224324424524624724824925025125225325425525625725825926026126226326426526626726826927027127227327427527627727827928028128228328428528628728828929029129229329429529629729829930030130230330430530630730830931031131231331431531631731831932032132232332432532632732832933033133233333433533633733833934034134234334434534634734834935035135235335435535635735835936036136236336436536636736836937037137237337437537637737837938038138238338438538638738838939039139239339439539639739839940040140240340440540640740840941041141241341441541641741841942042142242342442542642742842943043143243343443543643743843944044144244344444544644744844945045145245345445545645745845946046146246346446546646746846947047147247347447547647747847948048148248348448548648748848949049149249349449549649749849950050150250350450550650750850951051151251351451551651751851952052152252352452552652752852953053153253353453553653753853954054154254354454554654754854955055155255355455555655755855956056156256356456556656756856957057157257357457557657757857958058158258358458558658758858959059159259359459559659759859960060160260360460560660760860961061161261361461561661761861962062162262362462562662762862963063163263363463563663763863964064164264364464564664764864965065165265365465565665765865966066166266366466566666766866967067167267367467567667767867968068168268368468568668768868969069169269369469569669769869970070170270370470570670770870971071171271371471571671771871972072172272372472572672772872973073173273373473573673773873974074174274374474574674774874975075175275375475575675775875976076176276376476576676776876977077177277377477577677777877978078178278378478578678778878979079179279379479579679779879980080180280380480580680780880981081181281381481581681781881982082182282382482582682782882983083183283383483583683783883984084184284384484584684784884985085185285385485585685785885986086186286386486586686786886987087187287387487587687787887988088188288388488588688788888989089189289389489589689789889990090190290390490590690790890991091191291391491591691791891992092192292392492592692792892993093193293393493593693793893994094194294394494594694794894995095195295395495595695795895996096196296396496596696796896997097197297397497597697797897998098198298398498598698798898999099199299399499599699799899910001001100210031004100510061007100810091010101110121013101410151016101710181019102010211022102310241025102610271028102910301031103210331034103510361037103810391040104110421043104410451046104710481049105010511052105310541055105610571058105910601061106210631064106510661067106810691070107110721073107410751076107710781079108010811082108310841085108610871088108910901091109210931094109510961097109810991100110111021103110411051106110711081109111011111112111311141115111611171118111911201121112211231124112511261127112811291130113111321133113411351136113711381139114011411142114311441145114611471148114911501151115211531154115511561157115811591160116111621163116411651166116711681169117011711172117311741175117611771178117911801181118211831184118511861187118811891190119111921193119411951196119711981199120012011202120312041205120612071208120912101211121212131214121512161217121812191220122112221223122412251226122712281229123012311232123312341235123612371238123912401241124212431244124512461247124812491250125112521253125412551256125712581259126012611262126312641265126612671268126912701271127212731274127512761277127812791280128112821283128412851286128712881289129012911292129312941295129612971298129913

one additional line after a program plan is supplied to us David LACHMAN from an e program plan is mailed from the output terminal (corresponding to the stage the program is in). The line is the output from the program in a position 2, after the point is reached (from the g_{ij}), and a will be added to the structure of the unclassified program.

Stagger clear direct light terminals.

MODERNE SCHOOL OF ELECTRICAL ENGINEERING

```

Output Variable
A1.....D11      Group or program name input variable
A2.....D12      Grouped program name output variable
A3.....D13      Grouped direct input variable
A4.....D14      Grouped direct input variable
Input Variable
D1.....D11      Direct direct input variable

```

MOORE SCHOOL OF ELECTRICAL ENGINEERING UNIVERSITY OF PENNSYLVANIA		
MASTER PROGRAMMER FRONT PANEL NO. 1		
Iss. To: <i>John E. H. H.</i>	Project: <i>100-10000</i>	Spec. <i>1</i>
Given to: J. E. H. H.	Checked by: <i>J. E. H. H.</i>	Approved by: PX-8-301

Constant Transmitter

- 8 10-digit numbers read from punched card
- 2 10-digit numbers specified on rotary switches
- Each 10-digit number can be treated as 2 5-digit numbers
- 30 programs select which constant to transmit
- Relationships between card columns and constant values set on plugboard

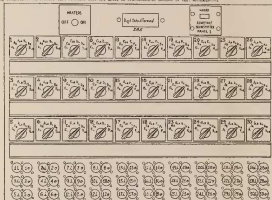
Constant Transmitter

[illegible]

1. **REMARK:** The transmission of a message is processed right and left representing this message. This message is to be submitted to a shift register [199] (see Fig. 1-10) by a logic table for transmission of the message to another unit of the system.

[illegible]

*That a police car travelled on these lines with the engine in position, I pulled down it is a complaint. Hence it is necessary to use a shifter as a starting arrangement to make the engine stop the work in emergencies because of this complaint.



— *Судья, уважаемый министр*

General Application of the American Formulation

[illegible]

Discrete-Time Dynamical Systems: Control

There are 30 channel (transmitter) program channels, with capable of transmitting some of the programs over the (light subject terminal), only one program control can be used at a time, which will be called on by the (transmitter) of a line.

1. Link program and creation of
1. Program menu has been created (1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000 19000 20000 21000 22000 23000 24000 25000 26000 27000 28000 29000 30000 31000 32000 33000 34000 35000 36000 37000 38000 39000 40000 41000 42000 43000 44000 45000 46000 47000 48000 49000 50000 51000 52000 53000 54000 55000 56000 57000 58000 59000 60000 61000 62000 63000 64000 65000 66000 67000 68000 69000 70000 71000 72000 73000 74000 75000 76000 77000 78000 79000 80000 81000 82000 83000 84000 85000 86000 87000 88000 89000 90000 91000 92000 93000 94000 95000 96000 97000 98000 99000 100000 101000 102000 103000 104000 105000 106000 107000 108000 109000 110000 111000 112000 113000 114000 115000 116000 117000 118000 119000 120000 121000 122000 123000 124000 125000 126000 127000 128000 129000 130000 131000 132000 133000 134000 135000 136000 137000 138000 139000 140000 141000 142000 143000 144000 145000 146000 147000 148000 149000 150000 151000 152000 153000 154000 155000 156000 157000 158000 159000 160000 161000 162000 163000 164000 165000 166000 167000 168000 169000 170000 171000 172000 173000 174000 175000 176000 177000 178000 179000 180000 181000 182000 183000 184000 185000 186000 187000 188000 189000 190000 191000 192000 193000 194000 195000 196000 197000 198000 199000 200000 201000 202000 203000 204000 205000 206000 207000 208000 209000 210000 211000 212000 213000 214000 215000 216000 217000 218000 219000 220000 221000 222000 223000 224000 225000 226000 227000 228000 229000 230000 231000 232000 233000 234000 235000 236000 237000 238000 239000 240000 241000 242000 243000 244000 245000 246000 247000 248000 249000 250000 251000 252000 253000 254000 255000 256000 257000 258000 259000 260000 261000 262000 263000 264000 265000 266000 267000 268000 269000 270000 271000 272000 273000 274000 275000 276000 277000 278000 279000 280000 281000 282000 283000 284000 285000 286000 287000 288000 289000 290000 291000 292000 293000 294000 295000 296000 297000 298000 299000 300000 301000 302000 303000 304000 305000 306000 307000 308000 309000 310000 311000 312000 313000 314000 315000 316000 317000 318000 319000 320000 321000 322000 323000 324000 325000 326000 327000 328000 329000 330000 331000 332000 333000 334000 335000 336000 337000 338000 339000 340000 341000 342000 343000 344000 345000 346000 347000</

The authors thank Dr. S. L. ...

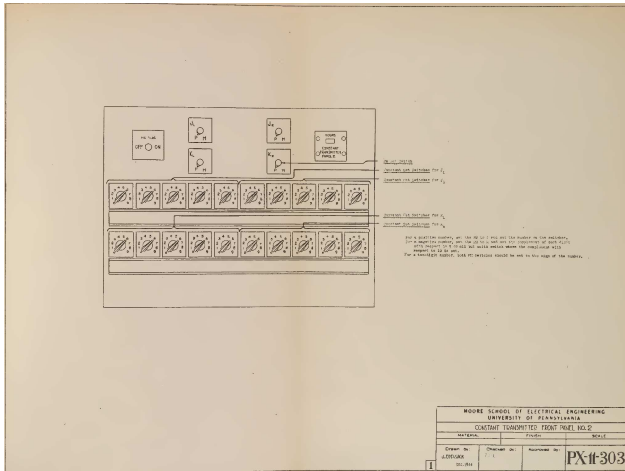
[illegible]

membrane is $\sim 10^{-2}$ cm.

Tragat palar malar, veldatla dar yongra nongra la

MOORE SCHOOL OF ELECTRICAL ENGINEERING UNIVERSITY OF PENNSYLVANIA		
CONSTANT TRANSFORMER FRONT PANEL NO.1		
MATERIALS	FINISHES	SCALE
Drawn by: L222608	Checked by: JWS 11/1/85	Approved by:
SEL-1946		PX-11-302

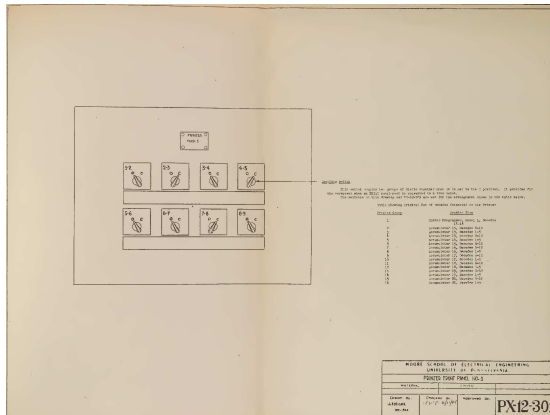
Constant Transmitter



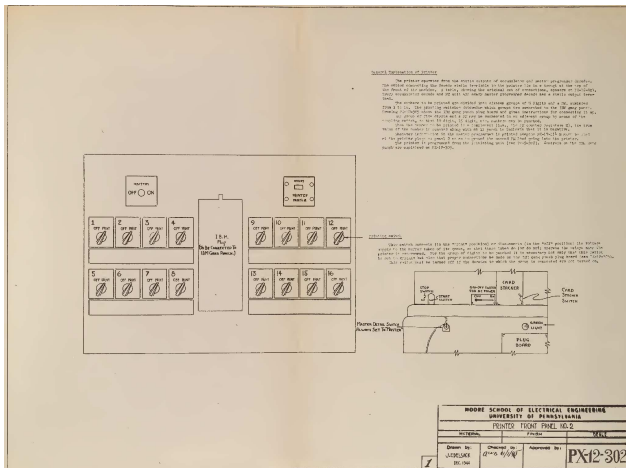
Printer/Punch

- 5 master programmer counter digits + 8 accumulators connected directly to printer/punch unit
- Relationship between accumulator digits and punch columns set on plugboard
- 5-digit groups enabled/disabled by control switches
- Approximately 600mS/card

Printer/Punch



Printer/Punch



Printer/Punch

FIGURE 1
TABLE 1

9-10	10-11	11-12	12-13
13-14	14-15	15-16	16-17

NOTE: THE ABOVE TABLE IS A REPRESENTATION OF THE PUNCH CARD.

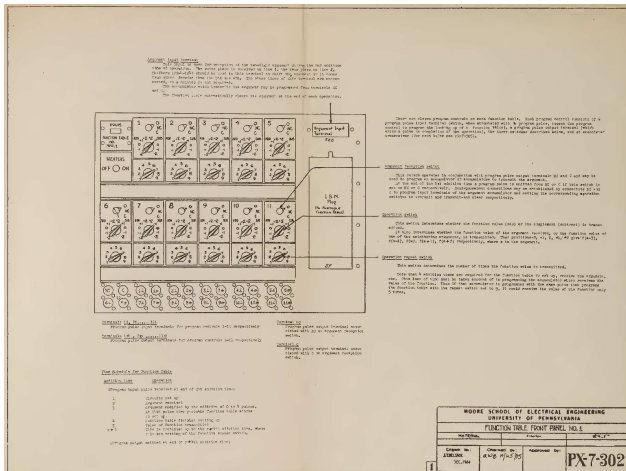
MOORE SCHOOL OF ELECTRICAL ENGINEERING
UNIVERSITY OF PENNSYLVANIA
PRINTED PUNCH PANEL NO. 3

Checked by J. B. BROWN	Checked by J. B. BROWN	Approved by J. B. BROWN	PX12-303
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Function Table

- Optimized for interpolation
- Each table supports two outputs (A and B)
- Each table stores 104 entries $f(-2) \dots f(101)$
- Argument value 0–100 sent from accumulator
- FT programs output select $\pm f(n - 2)$, $\pm f(n - 1)$, $\pm f(n)$, $\pm f(n + 1)$ or $\pm f(n + 2)$
- FT programs include repeat selection
- Where instructions were stored in sequential instruction mode

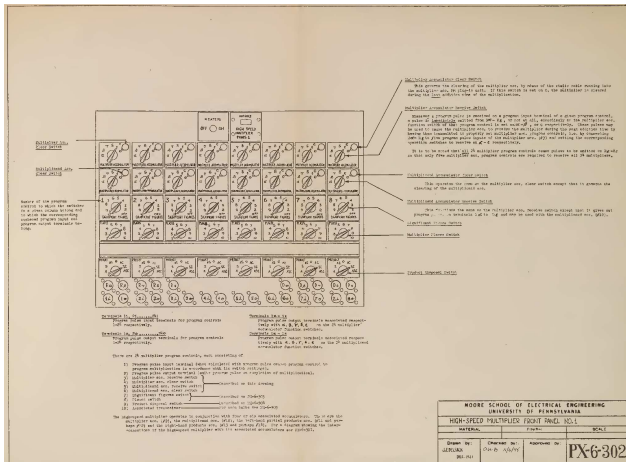
Function Table



Multiplier

- 3 racks
- p -digit multiplier
- Computes in $p + 4$ addition times
- Uses digit multiplication table
- Fixed connections to accumulators:
 - Multiplier
 - Multiplicand
 - Product

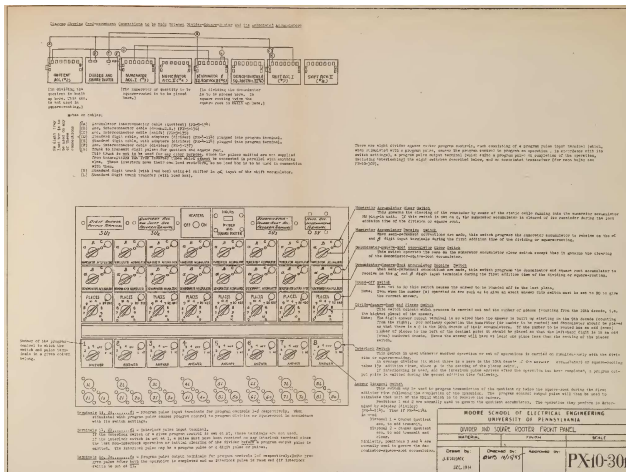
Multiplier



Divider/Square Rooter

- Approximate division and square roots
- Division in $14 + 2(p - 2) + 2$ addition times
- Square roots in $15 + 2(p - 2) + 2$ addition times
- Associated accumulators:
 - Numerator (dividend/radicand)
 - Denominator (divisor/root)
 - Shift accumulator
 - Quotient

Divider/Square Rooter



Programming (pre April 1948)

- Unit operations selected by panel switches
- Sequencing:
 - Switch settings on master programmer
 - Cables carrying programming pulses

Programming (post April 1948)

- Machine configuration to implement instruction set processor
- Instructions stored on portable function tables
- Multiple instruction set proposals:
 - 51-code design: uses only original ENIAC hardware
 - 60-code design: uses new converter unit
 - 94-code design: uses new converter unit

Memory Enhancement

- Early suggestion of accumulators without arithmetic
- Proposal for delay line register to be supplied by EMCC
- 100 word core memory module in 1953 supplied by Burroughs

Questions?