The ENIAC: Then and Now

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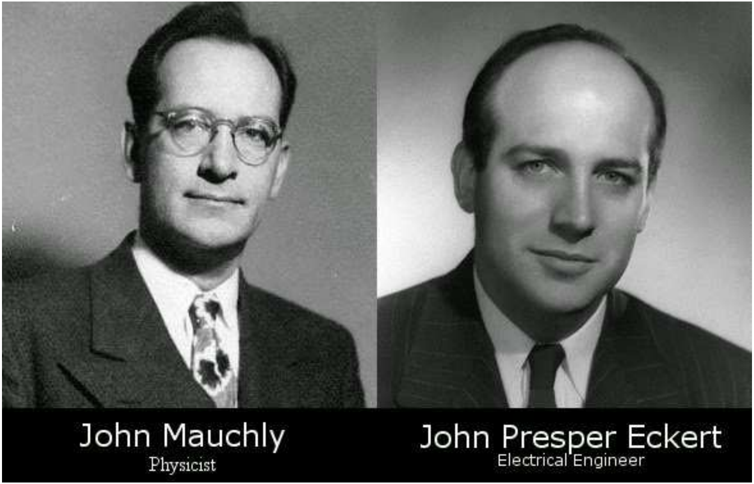
The ENIAC

What Is ENIAC?

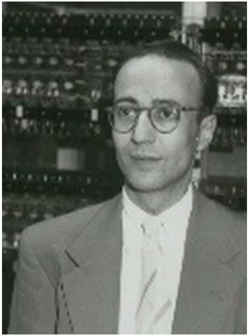
- Large-scale computing system
- Contracted in 1943 for the US Army
- Built during WWII
- Dedicated February 15, 1946
- Converted to sequential instruction execution in 1948
- Retired 1955
- Used for:
  - Atomic bomb development
  - Ballistics trajectories
  - Number theory
  - Weather prediction
  - and more

Key People


John Mauchly
Physicist
John Presper Eckert
Electrical Engineer

Key People

Herman Goldstine



Arthur Burks

Harry Huskey

Key People

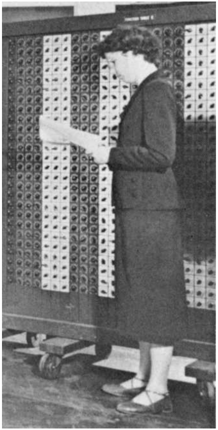
Kay Mauchly

Fran Bilas

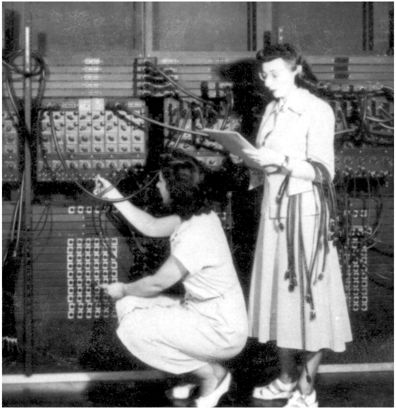
Jean Bartik

Key People

Betty Holberton



Ruth Lichterman Marlyn Wescoff



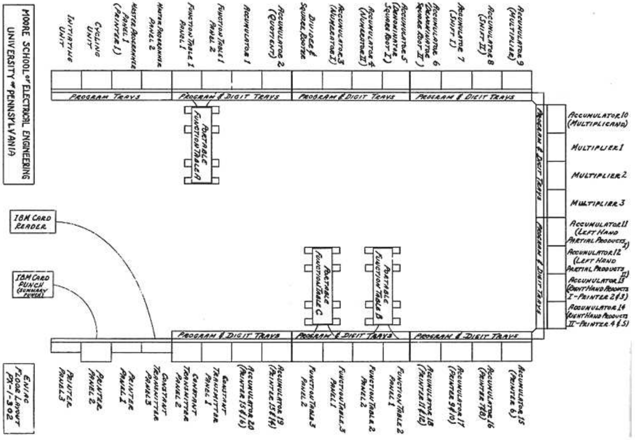
Common Statistics

- 40 racks, each 8' by 2'
- About 18,000 tubes
- 100KHz basic clock
- 200μS addition time
- About 150KW of power
- 29 power supplies
- 78 DC voltages

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
- Very parallel

> This was a highly parallel machine, before von Neumann spoiled it.
> — D.H. Lehmer

- Initially programmed with wires and switches
- Feels like a dataflow architecture

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

Hand-Held Control

Accumulator

- 10 digits + sign (P or M)
- Negative numbers stored as M + 10s 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)

Decade Counter Module

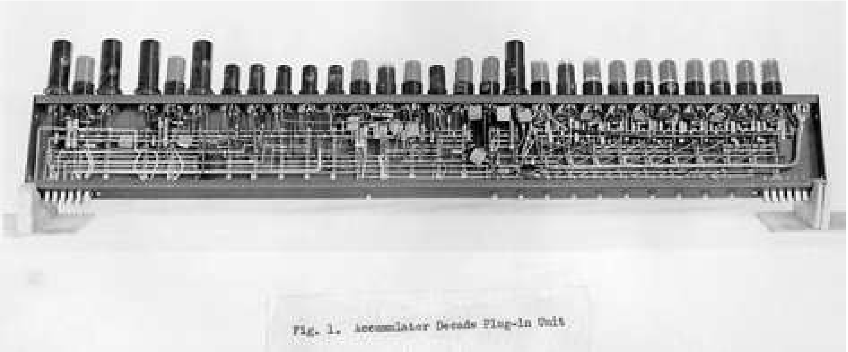
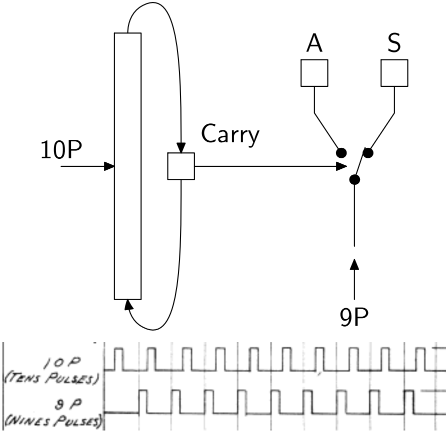


Fig. 1. Accumulator Decade Plug-in Unit

Reading From Accumulator



How it Works

- Add Accumulator 3 to Accumulator 4
- Accumulator 3 has 15 and Accumulator 4 has 27
- Control signal sent to both accumulators
- Accumulator 3 program sends 1 pulse on 10s line and 5 pulses on 1s line
- Accumulator 4 program receives pulses from Accumulator 3:
  - 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

Multiplier

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

Multiplication Example

- 42 times 347
- $4 \times 347 = 1200 + 160 + 28$
  - Left-hand partial product: 1120000000
  - Right-hand partial product: 0268000000
- $2 \times 347 = 600 + 800 + 14$
  - Add to LHPP: 0001000000
  - Add to RHPP: 0068400000
- LHPP: 1121000000, RHPP: 0336400000
- Add: 1457400000

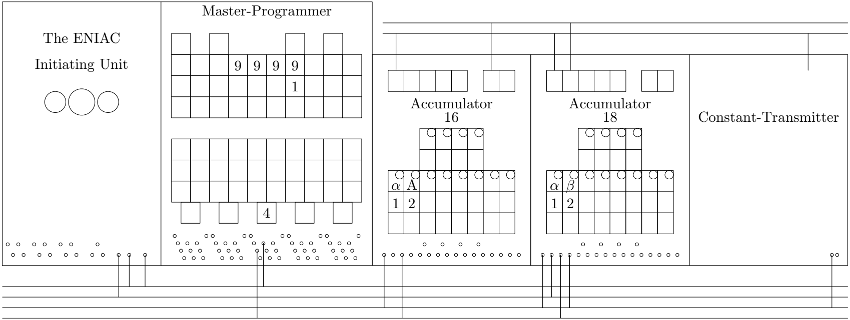
Master Programmer

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

Table of Squares

- Based on $(x+1)^2 = x^2 + 2x + 1$
- Let x be in Acc 16 and $f(x) = x^2$ be in Acc 18
- Algorithm:
    1. Initialize the values $f(x) = 0$ and $x = 0$
    2. For $x < 9999$:
        (a) Add $2x$ to $f(x)$
        (b) Add 1 to $f(x)$
        (c) Add 1 to x
        (d) Punch card with x and x^2

Table of Squares



Configuration

- Step 1: Clear sets all accumulators to 0
- Step 2: Initiated by program pulse on 1-1
  - Pulse from 1-1 enters master programmer on terminal Ci
  - Counter for Stepper C increments
  - If ≤ 9999 output program pulse on C1o connected to 1-4
  - Otherwise output program pulse on C2o not connected

Configuration

- Step 2a: Initiated by pulse on 1-4
  - 1-4 triggers Program 6 (via 6i) on both Acc 16 and 18
  - Acc 16, Prog 6: operation A, repeat 2
  - Acc 18, Prog 6: operation β, repeat 2
  - Acc 16 output A connected to data trunk 2
  - Data trunk 2 connected to Acc 18 input β
  - On completion, Acc 18 outputs control pulse on 6o connected to 1-3

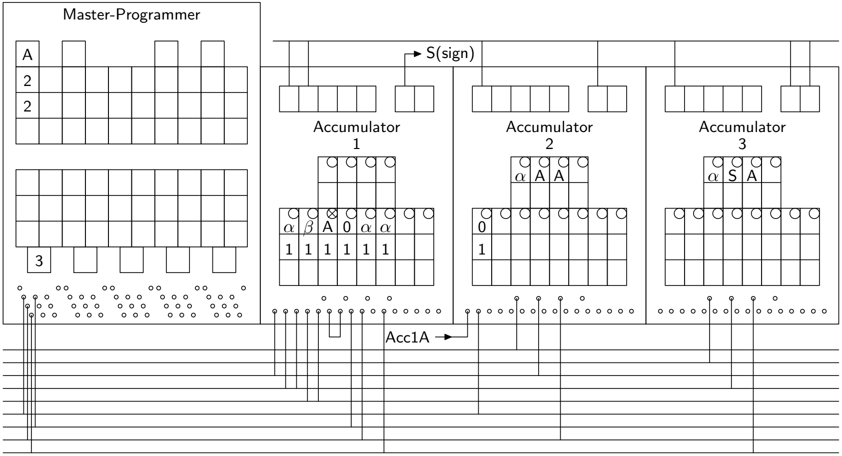
Configuration

- Steps 2b and c: Initiated by pulse on 1-3
  - 1-3 triggers Program 5 (via 5i) on both Acc 16 and 18
  - 1-3 triggers Program 26 (via 26i) on constant transmitter
  - Acc 16, Prog 5: operation α, repeat 1
  - Acc 18, Prog 5: operation α, repeat 1
  - Cons Xmit, Prog 26: send J (=1)
  - On completion, Acc 18 output control pulse on 5o connected to 1-2

Configuration

- Step 2d: Initiated by pulse on 1-2
  - 1-2 trigger printer, via Pi on initiating unit
  - On completion of transfer, output control pulse on Po connected to 1-1
  - Pulse on 1-1 restarts the sequence

Maximum



Master-Programmer
A
2
2
3
S(sign)
Accumulator 1
α
β
A
0
α
α
1
1
1
1
1
1
Accumulator 2
α
A
A
0
1
Accumulator 3
α
S
A
Acc1A

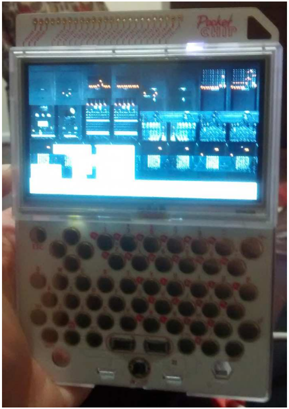
Programming

- Pre April 1948
  - Unit operations selected by panel switches
  - Sequencing:
    - Switch settings on master programmer
    - Cables carrying programming pulses
- Post April 1948
  - "Programming" 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

Simulator Examples



Questions?

http://cs.drexel.edu/~bls96/eniac/eniac.html