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
• 40 racks, each 8’ by 2’
• About 18,000 tubes
• 100KHz basic clock
• 200µS addition time
• About 150KW of power
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
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 + 10s complement
- 5 inputs: $\alpha, \beta, \gamma, \delta, \text{ and } \epsilon$
- 2 outputs: A and S
- 12 programs:
  - Operation: $\alpha, \beta, \gamma, \delta, \epsilon, 0, A, AS, \text{ or } S$
  - Clear/correct
  - Repeat count (on programs 5–12)
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

Fig. 1. Accumulator Decade Plug-In Unit
Decade Counter Schematic
• 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
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
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
• 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
Function Table

- Optimized for interpolation
- Each table supports two outputs (A and B)
- Each table stores 104 entries \( f(-2) \ldots f(101) \)
- 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
Multiplier

- 3 racks
- $p$-digit multiplier
- Computes in $p + 4$ addition times
- Uses digit multiplication table
- Fixed connections to accumulators:
  - Multiplier
  - Multiplicand
  - Product
• 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
• Unit operations selected by panel switches
• Sequencing:
  – Switch settings on master programmer
  – Cables carrying programming pulses
• 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?