Go Meets the ENIAC: Coming Full Circle

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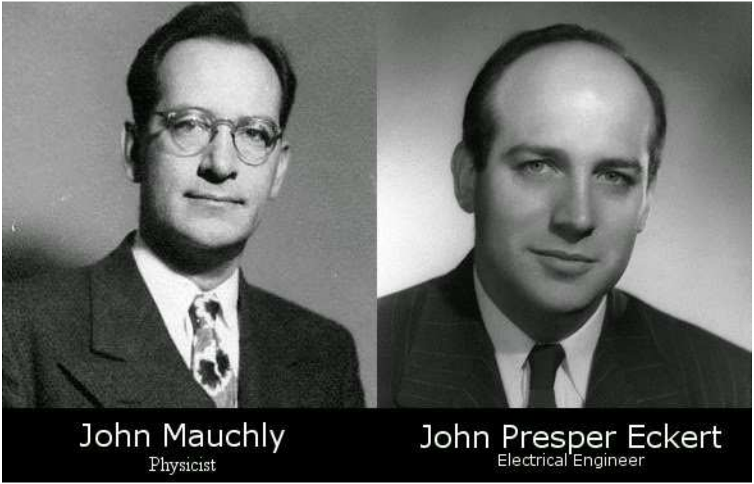
What Is ENIAC?

- 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

The ENIAC

Key People



John Mauchly
Physicist
John Presper Eckert
Electrical Engineer

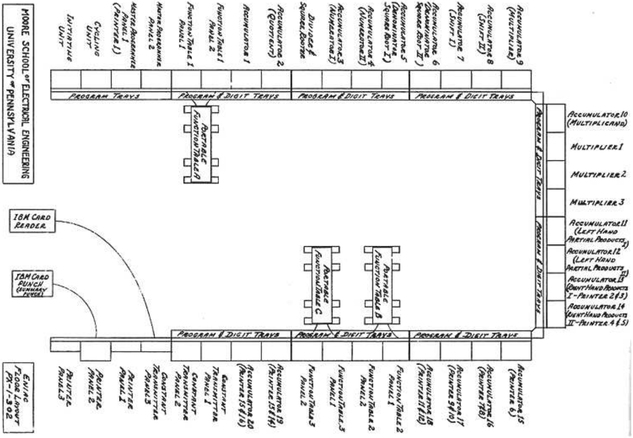
Common Statistics

- 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

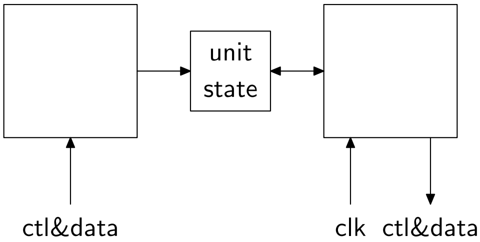
> This was a highly parallel machine, before von Neumann spoiled it.
> — D.H. Lehmer

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

Simulating Parallelism

- Parallel Hardware: Faithful, but limited applicability, save for a later project
- Serialized simulation: Easier to implement, but not as revealing of subtlties of parallelism
- Multi-threaded concurrency: Helps expose underlying programming difficulties, and can take advantage of supporting hardware parallelism:
  - pthreads
  - Plan9 (P9P) thread library
  - Natural fit for goroutines

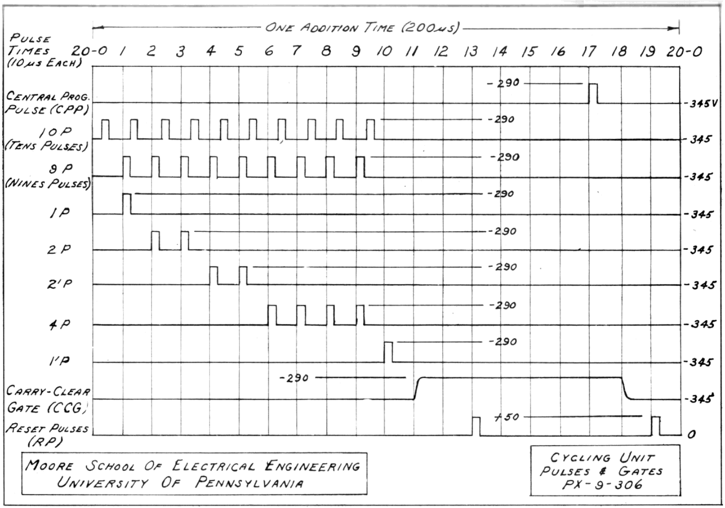
Unit Simulation Structure



Pulse Transmission

- Standardized pulse shape
- Naturally suited to the use of Go channels
- Control terminals
  - Single line for pulses
  - One channel message per pulse
- Data terminals
  - 11 pulse lines (10 digits + sign)
  - Not necessarily synchronous
  - In practice, parallel pulses often simultaneous
  - All 11 lines encoded in single channel message

Clock Signals



Clock Distribution

- Unique clock channel per unit
- Clock lines encoded as single integer message
- Separate goroutine relays clock messages to unit channels

Pulse Trays and Trunks

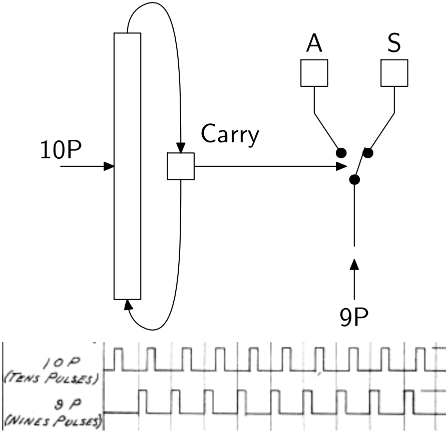
Trunk Simulation

- One goroutine per trunk
- Array of channels from each transmitter
- Array of channels to each receiver
- Listen simultaneously to all transmitter channels
- Relay each message to all receiver channels
- Perform handshaking

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)

Reading From Accumulator



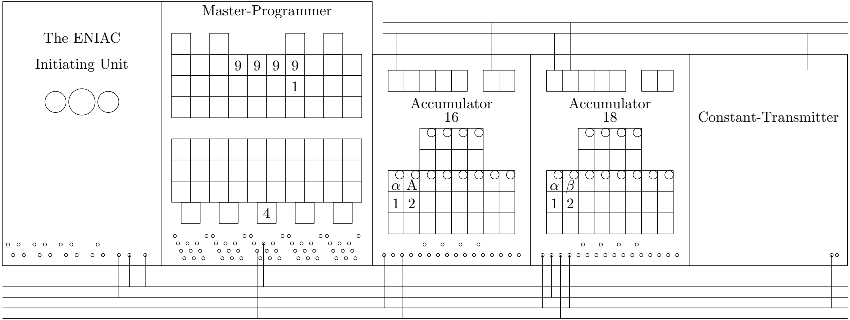
Master Programmer

- 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



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

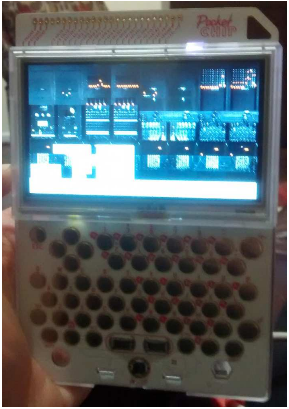
User Interface

- Main interface (code perspective) is simple command line:
  - Single letter commands
  - Abbreviations for units
  - Format looks like a sort of "ENIAC Assembly Language"
- Configuration files parsed by command line interpreter (thus are scripts)

Graphical Interface

- TCL/Tk does the heavy lifting
- Run wish in child process with pipes
- Send Tk commands to update the display
- Button presses send commands interpreted by command line interpreter
- Background image created by ray tracing

Simulator Examples



Key ENIAC Engineer

Harry Huskey

Key Go Developer

Ken Thompson

Questions?

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