The Electronic Revolution: Part 1

An overview of the computers and computing devices that relied solely on electronic means for completing calculations.

James Tam

Computing Technology (Pre WWII - WWII)

- As discussed in previous sections computers prior to this period were entirely mechanical or electromechanical in their design.

Mechanical "computer"

- World War II: the electronics industry (e.g., radio) was given a tremendous boost.

James Tam

Computing Technology (Pre WWII - WWII): 2

- Many people independently thought of using electronics in a calculating machine but the costs were high.
  - First attempt: Schreyer and Zuse
  - First prototype: Atanasoff and Berry
  - First fully working machine: Mauchly and Eckert
- This type of technology would derive its results using electronics (non-mechanical, mechanical parts were incidental rather than a key part of the calculation).

Electronic vacuum tube

Mataresephotos
http://matarese.com/photo/402-mullard-el84-vacuum-tube

James Tam

Electronic Computer Projects

- The ABC
- The ENIAC
- The British code breaking machines

James Tam

The People Behind The ABC (Atanasoff-Berry Computer)

- John Atanasoff
  - A professor at Iowa State College (now Iowa State university)

- Clifford Berry
  - A graduate student studying under Atanasoff

James Tam

Images: "A history of computing technology" (Williams)

Motivations For Developing The ABC

- Atanasoff was researching methods of solving complex physics equations.

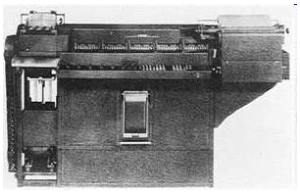
- The drudgery of using the calculators of the day motivated him to find something better.

www.xnumber.com

James Tam

Motivations For Developing The ABC (2)

- He started by modifying the small IBM calculator that was leased to the college to see if it could solve these problems.



www.columbia.edu

James Tam

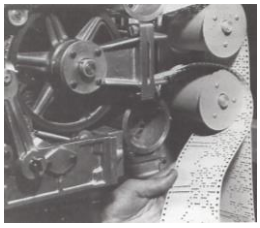
Motivations For Developing The ABC (3)

- His modifications were extensive
- The staff at IBM weren't happy with the modifications

James Tam

Motivations For Developing The ABC (4)

- Atanasoff's experiences with modifying the IBM tabulator convinced him that mechanical-based technology was unlikely to have the necessary speed and durability.



James Tam

Image: "The History of Computing Technology" (Williams)

Motivations For Developing The ABC (3)

- Atanasoff then decided to build his own machine.
- Unfortunately this proved to be more of a daunting task than he first anticipated.

- After a particularly frustrating night he decided to take a break from the lab.

- This lead to an astonishing break through!

James Tam

Wav file from "James Tam"

The First Electronic Computer: The ABC

- After enlisting the aid of Berry and several years of hard work the ABC was *nearly* completed at a cost of $6000 (including the $450 paid to Berry) in 1942.
- It was the first *prototype* electronic computer!

A photo of Clifford Berry and the ABC, courtesy of Dr. Atanasoff

James Tam

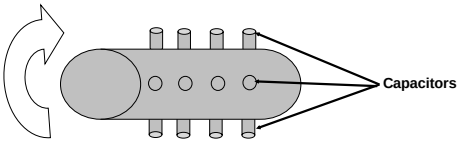
The First Electronic Computer: The ABC

- (At this time the US was involved in the second World War so the government demanded trained technical people to join the war effort).
  - In 1942 Atanasoff left the project (Naval Ordnance Laboratory).
  - The ABC never did become fully operational.

James Tam

The First Electronic Computer: The ABC (2)

- It was the first machine to incorporate regenerative memory (Williams) that was similar to the kind used in modern D-RAM
- But it was not a stored program computer.



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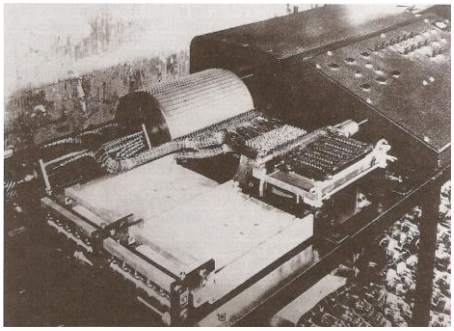
ABC: Rotating Drum Memory



James Tam

Image: "A History of Computing Technology" (Williams)

The ABC: Technical Specifications

- Arithmetic unit:
  - 300 vacuum tubes (addition and subtraction)
- Control and memory
  - 300 vacuum tubes

James Tam

The ABC: Controversy

- The fate of Atanasoff and Berry
- Who developed the first electronic computer
  - ABC creators or the creators of the later machine (ENIAC)?
- Getting the 'stamp' on their work
  - Filing issues
- Court decision
- General view of the attribution of credit

James Tam

ABC: Significance

- It included a number of firsts:
  - Demonstrating the use of electronics in a digital calculating machine (excluding Helmut Schreyer and Konrad Zuse).
  - Incorporation of regenerative memory.

James Tam

Videos

- Vision Atanasoff: Part I & II
- Operation of ABC computer: punch cards
- (From the last section)
  - ABC and Atanasoff ~23 – ~30e, last viewed Oct. 2025
  - https://www.youtube.com/watch?v=qundvme1Tik

James Tam

The ENIAC: Place

http://www.archives.upenn.edu

- 1923: The Moore School of Electrical Engineering was founded.
- Throughout it's history many prominent researchers would visit the school
  - Vannevar Bush
  - John von Neumann
- 1930: The school enters into a relationship with the U.S. Army (Aberdeen Proving Ground: Maryland).
- First project: constructing another Differential Analyzer.
  - Funded by the government (research proving ground)
  - 2 machines (one for Aberdeen and one for Moore)
  - Bush even 'loaned' his chief designer to the project
  - Finished in 1934

James Tam

Calculating Ballistic Trajectories: Details (Williams)

- Given that the following were known and constant.
  - Gun type (guns could be used for different purposes) and size
  - Type of shell being fired
  - Charge of the propellant used
  - Elevation of the gun
- Keep in mind that there is a great deal of variation in real life:
  - Guns ranged from ~5" to 18.1" (or more in rare cases).
  - Consider the possible elevations where battles have taken place (sea level up to the mountains).
  - Etc.
- A firing solution could be calculated from a ballistic table.
  - It would contain solutions to 3,000 trajectories
  - (Longer ranged guns would have to consider other factors: air pressure, humidity, wind speed).

James Tam

Calculating Ballistic Trajectories: Details (Williams): 2

- A *skilled operator* using a desk calculator could complete the results for a single trajectory in 20 hours.
  - 20 hrs./trajectory x 3000 trajectories = 60,000 hours for one table
  - (Assuming a 40 hour work week): 1,500 weeks or 28 years (no vacation)
  - (World War I: 1914 – 1918)
  - (World War II: 1939 – 1945)
  - To deal with the "man power" shortages many women were recruited.

http://www.cssu-bg.org

James Tam

Calculating Ballistic Trajectories: Details (Williams): 3

- Computers of the day (e.g., Differential Analyzer) could complete the results in 20 minutes (excluding set up time…remember hammer and wrenches!)
- These calculations excludes the requirements of the U.S. Navy (with their own set of challenges).

www.clipartbest.com

James Tam

The People Behind The ENIAC

- John Mauchly
  - Developed the designs for the ENIAC


From www.computermuseum.li

- J. Presper Eckert
  - Designed the individual circuits of the ENIAC


Image © Michael Denning from www.computerhistory.org

- Joseph Chedaker
  - Supervised the construction team

James Tam

John Mauchly (1907 – 1980)

- He received the Engineering Scholarship of the State of Maryland.
- 1925: He enrolled in Engineering at John Hopkins University.
- 1927: He enrolled for and was directly transferred to the Ph.D. physics program.
- 1933 – 1941: A professor of physics at Ursinus College

James Tam

J. Presper "Pres" Eckert (1919 - 1995)

- He came from a wealthy family

- In school he showed a great aptitude for mathematics.

James Tam

J. Presper Eckert (1919 - 1995): 2

- Enrolled in the Wharton Business school at the University of Pennsylvania.
- Transferred over to the Moore School of Engineering where he worked on:
  - Research on radar technology.
  - Improving the speed and accuracy of the school's Differential Analyzer.
  - 1941 became a laboratory assistant for a defense training summer course in electronics (funded by the United States Department of War)

James Tam

The Meeting Of Mauchly and Eckert

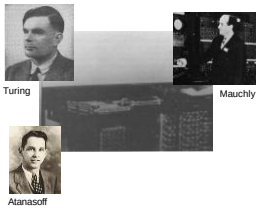
- John Mauchly
  - As mentioned he was a Physics professor at Ursin College.
- J. Presper Eckert
  - A lab instructor at the Moore School (government sponsored electronics course)

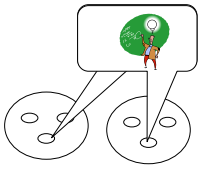
- When some staff positions became vacant at the Moore School (war) Mauchly was recruited into the engineering school.

James Tam

Atanasoff And The Moore School

- December 1940: American Association for the Advancement of Science meeting, Atanasoff and Mauchly first met.
- Summer 1941: Mauchly visits Iowa State college.






Eckert

James Tam

Image from "History of Computing Technology" (Williams)

Publications

- August 1942: Mauchly wrote his ideas in a paper "The Use of High Speed Vacuum Tube Devices for Calculating".
  - Contrast of electronic vs. mechanical approaches (details from Williams)
    - Differential Analyzer: 15 – 30 minutes
    - Electronic machine: 100 seconds (1.67 minutes)
  - Reaction at the time….ZZZZ
  - One year later….where is it???!!!

James Tam

The War Effort And The Moore School

- The calculation of ballistic tables was falling too far behind!

- April 9, 1943: Meeting between the Moore School and the Ballistic Research Laboratory people.
  - Mauchly and Eckert attempted to reconstruct the paper of notes made by Mauchly's secretary.
  - Moore School: proposed the name "Electronic Numerical Integrator" (Integrator: remember the Differential Analyzer).

James Tam

The War Effort And The Moore School (2)

- Mauchly: focused on the 'general' use of the machine (more than just Integrals).
- Army: add the phrase "and Computer".
- Thus the name: "Electronic Numerical Integrator" + "and Computer" was used. (ENIAC)

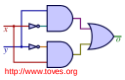
- January 1944: the design of the machine was complete enough so actual progress could be made on the machine itself (rather than on 'test circuits').
- July 1944: two accumulators, a power supply and signal generator could perform simple calculations.
- ???: complete and fully working (many later modifications were often just improvements).

James Tam

The ENIAC

- May 31, 1943: Work on the project began.

Eckert



Lt. Herman H. Goldstine

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Presper Eckert: Contributions

- A younger member of the team (remember he was a 'TA')
- Considerable hands on experience (radar research)

Elegant and new solution?

Brute force but proven to work?

- Little work time was wasted.

James Tam

The ENIAC: Results

- It was big!
  - Real big!!!!
  - x100 times bigger than other machines of the time
- "…the most complex bit of electronic ever put together" (Williams).
  - ~US telephone network

James Tam

Image: "A History of Computing Technology" (Williams)

The ENIAC: Results

- Dimensions:
  - 8' high x 3' wide x 100 long
- Weight:
  - Many tons!
- Energy consumption:
  - 140,000 watts (140 kilowatts)
- Vacuum tubes:
  - Original design: 5,000 needed
  - Completed design 18,000 used
    - Along with 1,500 relays and 10,000 capacitors
- Costs
  - Original budgeted cost: $150,000
  - Actual cost: Over $486,000

James Tam

The ENIAC: The Component 'Units'

- The ENIAC was divided up into component 'units'
- Each unit would be contained behind panels
- Behind the panels:
  - A unit would contain its own memory and control (vacuum tubes and relays).
  - There was also a complex array of switches, indicator lights and connector sockets.

James Tam

The ENIAC: Component Units, Williams

- Type 1: Memory: 20 accumulators
  - Each accumulator could store a 10 digit signed number
  - Accumulators could be combined to increase the number of digits.
- Type 2: Multiplication unit:
  - A hard wired single digit multiplication table
  - Similar to Napier's bones and paper: a complex multiplication would be determined by computing the partial products and then summing the products.
    - Partial products: 4 – 5 faster than technology that employs repeated additions.
    - Two ten digit numbers could be multiplied in under 3 milliseconds.
    - The ENIAC was an electronic implementation of the Harvard Mark I (electro-mechanical): Multiplication: ~6 seconds.

James Tam

The ENIAC: Component Units, Williams (2)

- Type 3: A combined division and square root unit
- Type 4: Three function tables: could store tables of function values
- Type 5: Input unit (120 punch cards/minute)
  - A memory buffer was constructed out of 8 relays
- Type 6: Output unit (100 punch cards/minute)
- Type 7: Master programmer (repeating instructions 'loops')

- The punch card machines were the greatest source of breakdowns in the ENIAC.
  - Normally it's a very reliable technology.

James Tam

The ENIAC: Bottleneck, Williams

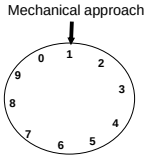
- The accumulators were frequently the limiting speed factor of the machine.
- Sometimes the 20 accumulators could not store all the partial results.
  - The results would then have to be printed and fed back into the machine as a new calculation.
- Multiplication and division were so resource intensive (partial values) that although the machine could perform them quickly if all the results could be stored they were usually avoided whenever possible:
  - Multiple adds/subtractions
  - Bit shifting
  - Using the principle of constant differences between functions (Babbage)

James Tam

Memory Of The ENIAC

- Many of the components were just electronic equivalents of the mechanical version.
- E.g., to store a single digit:

Mechanical approach



The approach used in the ENIAC

"A History of Computing Technology" (Williams)

James Tam

The ENIAC: Cooling, Williams

- Vacuum tubes technology produces a great deal of heat.
- The computer was air cooled
  - Two 12 horse power motors pumped 600 cubic feet of air per minute through each panel
  - Contrast: home ceiling fans max ranges ~400 – several thousand cubic feet of air (source unknown)
- Each panel had it's own thermometer
  - The temperature for each panel could be individually regulated
  - There was fail safe that would shut down the entire machine if any panel exceeded 120 F/49C.

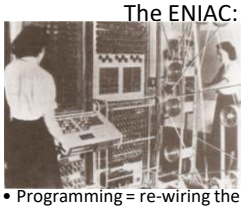
James Tam

The ENIAC: Cooling (2)

- During servicing the panels had to be opened (air leak) and the fail safe disabled.
  - Failure rate: 18,000 vacuum tubes, one would fail every 2 – 3 days.
  - A floor fan could be used to cool a panel during this time.
  - Due to an unfortunate oversight a fire occurred that destroyed 2 units

James Tam

The ENIAC: Programming



- Programming = re-wiring the cables going to/from sockets.
- Bus wires determines:
  - Which units are activated
  - Which units to send data
  - Whether instructions should be repeated
  - If a memory accumulator should be reset to zero
  - Etc.

James Tam

Image: "A History of Computing Technology" (Williams)

The ENIAC: Programming (2)

- Numerical buses
  - Transmit the number and the complement of the number (subtraction via negate and add)
  - 12 wires:
    - 10 wires for up to 10 digit numbers
    - 1 wire for the sign
    - 1 wire for grounding the connection.

James Tam

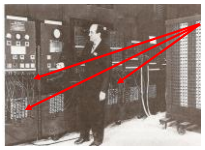
The ENIAC: After Completion

- Spring 1945: the ENIAC was functioning well although it was still considered in test mode (beta).
  - It had run actual ballistic programs as well as calculations for the Los Alamos atomic energy group.
- Later in 1945: dismantled and shipped to the Ballistics Laboratory (Aberdeen, Maryland).
  - The war was over so the machine was put to work on a wide variety of problems. (For several years the ENIAC was the only large scale, electronic computer used daily).
- Vacuum tube technology: very reliable when 'always on'
- It continued to provide good, reliable service for another ten years.

James Tam

The ENIAC: Later Enhancements

- A magnetic drum to store intermediate results.
- More (core) memory added:
  - Store intermediate results
  - Act as an input/output buffer
  - 100 words (digits) in a cabinet (7' high x 2' wide x 2.5'deep)!
- The ENIAC was not originally conceived as a stored program computer.



'Hard wired' computer program instructions

"A History of Computing Technology" (Williams)

James Tam

The ENIAC: Programming (3)

- Later the ENIAC became programmable (modern sense):
  - The machine's operating speed as now slower but this was more than offset by the decreased time needed to setup the machine (Williams)

James Tam

The ENIAC: The End, Williams

- It was shut off for the final time on October 2, 1955.
- 10 years at Aberdeen Proving Grounds (Maryland) the ENIAC was conjectured to have completed more calculations than the whole of the human race prior to 1945!
- Parts of the machines are on display at the National Museum of American History (Smithsonian) and other locations (e.g., School of Engineering and Applied Science at the University of Pennsylvania).

James Tam

Videos

- ENIAC (Last accessed October 2024)
  - https://www.youtube.com/watch?v=bGk9W65vXNA
  - Video courtesy of The Computer History Archives: https://www.computinghistory.org.uk/
- Mauchley, the person behind the technology, and the ABC (last accessed October 2024)
  - https://www.youtube.com/watch?v=MdeQx4I3iHw
  - Video courtesy of The ISU library (Iowa State University Library, Special collections and University archives audiovisual collection)

James Tam

The ABC And The ENIAC (Williams)

- The ABC was the first *prototype* (partially working) electronic computer (not quite completed).
- The ENIAC was the first *fully operational* electronic computer

James Tam

Tam's Clarification Of A Common Source Of Confusion

- An assertion you may see from different sources: "The ENIAC was the first programmable computer".
- Tam:
  - Not really. Programmable computers utilize high speed rewritable memory (such as DRAM)
  - The ENIAC (July 1944[1]) was 'programmable' by rewiring the hardware which hardly qualifies it as programmable.
    - It's initial design didn't even incorporate programs to be read from punch card/tape.
  - Furthermore some earlier machines could be 'programmed' this way.
    - Harvard Mark I (May 1944): with rewiring the machine's 'programming' moved the decimal point from the 15th to the 16th digit.
    - Zuse's Z1 (worked on 1936-1938[2])

1: Two accumulators, a power supply and signal generator could perform simple calculations.
2: Bauer, Friedrich Ludwig (2009-11-05). **Origins and Foundations of Computing: In Cooperation with Heinz Nixdorf Museums Forum**. Springer Science & Business Media. p. 78

James Tam

After This Section You Should Now Know: All Sections

- What is the difference between electronic and mechanical/electro mechanical computing devices
- What were the three electronic computer projects
- What was the first electronic computer (partially and fully completed)
- The technical specifications of the first electronic computers
- The general appearance and cost/resources used in the building of the first electronic computers
- The history behind the names of the first electronic computers
- Who were the people behind these computers and what were some of the major events in their lives
- What were the approximate dates/time frames of significant developments

James Tam

After This Section You Should Now Know: US

- The ABC
  - What was the motivation behind its development
  - What were the circumstances behind its conception
  - How did the regenerative memory work
- The ENIAC
  - The major events in the history of the Moore school
  - The type of research work was done at the Moore school
  - What were the events that lead up to the development of the ENIAC
  - What were the different parts of the ENIAC, what they consisted of and how they worked
  - What was the major computational bottleneck
  - Why multiplication and division operations were theoretically fast but in practice slow and what alternatives were employed

James Tam

After This Section You Should Now Know: US (2)

- (The ENIAC continued)
  - What was a 'unit' in the ENIAC and what did it consist of
  - How was numerical information stored in memory
  - How the cooling system worked
  - The method of programming the ENIAC
  - What were some of the later enhancements
  - The eventual fate of the ENIAC

James Tam

References

- "A history of computing technology", Michael R. Williams 2nd Ed (IEEE 1997)

James Tam

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