15-292 History of Computing

The Origins of Computing

Where do we start?

- We could go back thousands of years
  - Mathematical developments
  - Manufacturing developments
  - Engineering innovations
  - The wheel?
- The basis of all modern computers is the binary number system
- 0001, 0010, 0011, 0100, 0101, 0110, 0111…

Origin of the Binary Number System

- 2nd Century BC
  - Chinese mathematicians devise a positional decimal notation based on “number rods”
- 4th Century AD
  - Mayan astronomer-priests begin using a positional number system based on base 20
- 4th to 5th Century AD
  - positional decimal system with a sign for zero appears in India
  - first system in history capable of being extended to a simple rational notation for all real numbers
- For the next seven centuries, the decimal number system becomes the primary system to represent numbers.

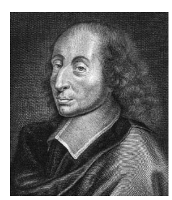
Origin of the Binary Number System

- 1600
  - Thomas Harriot, English astronomer, mathematician and geographer
  - decomposition of integers from 1 to 31 into powers of 2.

- 1623
  - Francis Bacon, English philosopher
  - Devised a binary code for the alphabet
  - A=aaaaa, B=aaaab, C=aaaba, D=aaabb, etc.

Origin of the Binary Number System

- 1654
  - Blaise Pascal (1623-1662)
  - *De numeris multiplicibus ex sola characterum numericorum additione agnoscendis*
  - Gives a general definition of a number system for an arbitrary base m, where m may be any whole number greater than or equal to 2



- 1670
  - Bishop Juan Caramuel y Lobkowitz
  - published a systematic study of number systems with non-decimal bases including 2, 3, 4, 5, 6, 7, 8, 9, 12, 20, 60.

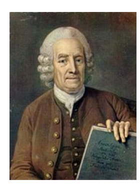
Origin of the Binary Number System

- 1679
  - Gottfried Wilhelm Leibniz
  - Published a study of binary numbers
  - In 1685, Father Joachim Bouvet, mathematician and missionary in China, sends Leibniz the 64 figures formed by the hexagrams of the Yijing
  - Leibniz concludes, wrongly, that the binary number system was created in China

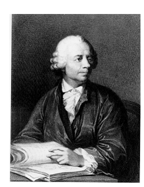
- 1701
  - Thomas Fantel de Lagny, French mathematician
  - Demonstrates merits of binary independently

Origin of the Binary Number System

- 1708
  - Emanuel Swedenborg proposes decimal notation should be replaced for general use by octal.



- 1732
  - Leonhard Euler, Swiss mathematician
  - used binary notation in correspondence



- 1746
  - Francesco Brunetti, Italian mathematician
  - Derives a table of decimal values of powers of 2 up to 240.

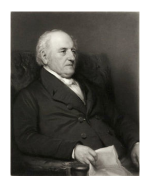
Origin of the Binary Number System

- 1775
  - Georges Brander of Augsburg uses binary number system to encode private financial accounts.

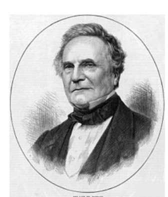
- 1798
  - Adrien Marie Legendre, French mathematician
  - published works on conversions from the binary system to the octal system and to the hexadecimal system

Origin of the Binary Number System

- 1810
  - Peter Barlow, English scientist, published an article on the transformation of a number from one base to another and its application to duodecimal arithmetic

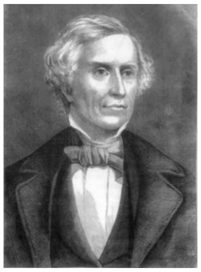


- 1826
  - Heinrich W. Stein, mathematician, published an article about various relationships between non- decimal number systems.
- 1834
  - Charles Babbage, English mathematician, analyzed various number systems for use in his Analytical Engine



Origin of the Binary Number System

- 1837
  - Samuel F. Morse
  - Invents the telegraph, which transmits messages by means of electrical impulses
  - Two “symbols” in language:
    - dot – a short electrical pulse
    - dash – a longer electrical pulse
  - Letters were made up of combinations of dots and dashes



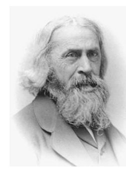
Origin of the Binary Number System

A	. —	N	— .	&	. . . .
B	— . . .	O	. .	1	. — — .
C	. . .	P	. . . . .	2	. . — . .
D	— . .	Q	. . — .	3	. . . — .
E	.	R	. . .	4	. . . . —
F	. — .	S	. . .	5	— — —
G	— — .	T	—	6	. . . . . .
H	. . . .	U	. . —	7	— — . .
I	. .	V	. . . —	8	— . . . .
J	— . — .	W	. — —	9	— . . —
K	— . —	X	. — . .	0	—— ———
L	——	Y	. . . .		
M	— —	Z	. . . .		

Origin of the Binary Number System

- 1853
  - Augustus de Morgan, English logician, publishes an argument that non-decimal number systems should be taught in schools and universities

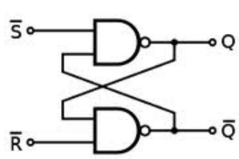
- 1876
  - Benjamin Pierce proposes new notation for binary (dot for 0, horizontal line for 1) saying it is more “economical”

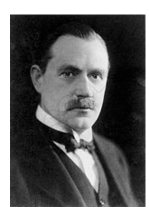


- 1887
  - Alfred B. Taylor publishes “Which base is best?” and concludes it is base 8.

Origin of the Binary Number System

- 1919
  - William H. Eccles and Frank W. Jordan invent the flip-flop, an electronic device consisting of two triodes.
  - An electrical impulse arriving at one of its inputs reverses the state of each of the triodes (a bistable circuit).
  - This eventually leads to more researchers looking at binary as the eventual number system for electronic computers.





Eccles

Origin of the Binary Number System

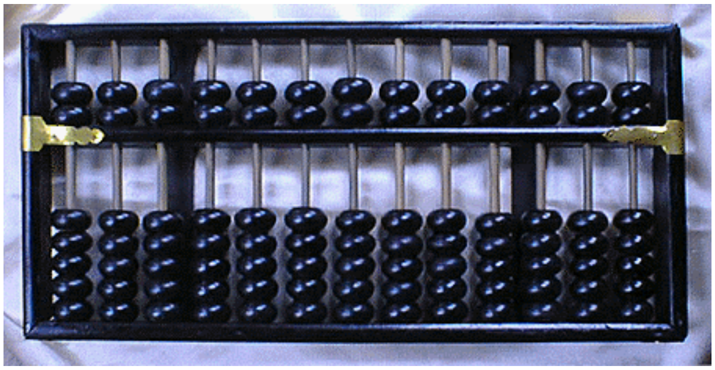
- 1932
  - C.E. Wynn-Williams created a binary electronic counting device using gas thyratron tubes
- 1936
  - Raymond L.A. Valtat takes out a patent in Germany on a design for a binary calculating machine.
- 1937
  - Alan Turing sets about constructing an electromechanical binary multiplier
- 1945
  - John von Neumann advocates the binary system for representing information in electronic computers

Benefits of Binary

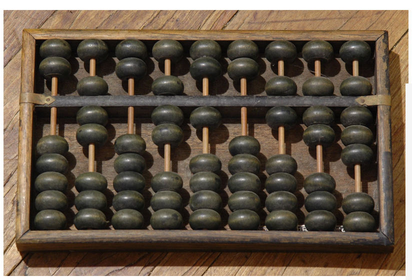
- Much simpler circuits for arithmetic
  - Multiplication
    - much simpler circuits - there are only 4 outcomes
    - 0 * 0 = 0   0 * 1 = 0   1 *0 = 0   1 * 1 = 1
    - Same result as Boolean logical AND operation
  - Addition
    - 0 + 0 = 0   0 + 1 = 1   1 + 0 = 1   1 + 1 = 10
    - Same result as Boolean logical XOR operation
- In electronic circuits, only two voltage levels needed to be maintained to represent 0 and 1.

Early Computational Devices

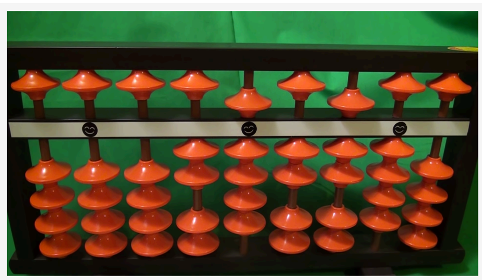
- (Chinese) Abacus - 2nd Century BC
  - Used for performing arithmetic operations



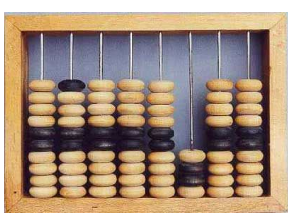
Examples



suanpan



soroban



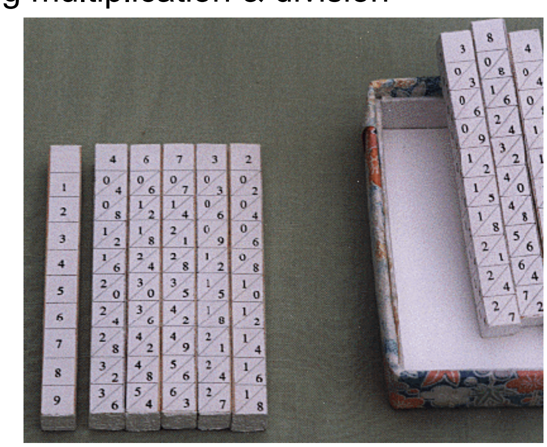
schoty

Computing sum 1 + … + 50

Early Computational Devices

- Napier's Bones, 1617
  - For performing multiplication & division

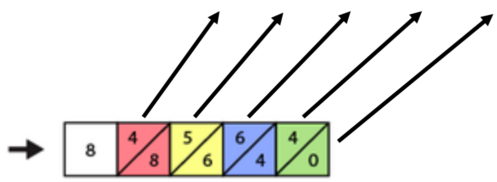
John Napier
1550-1617



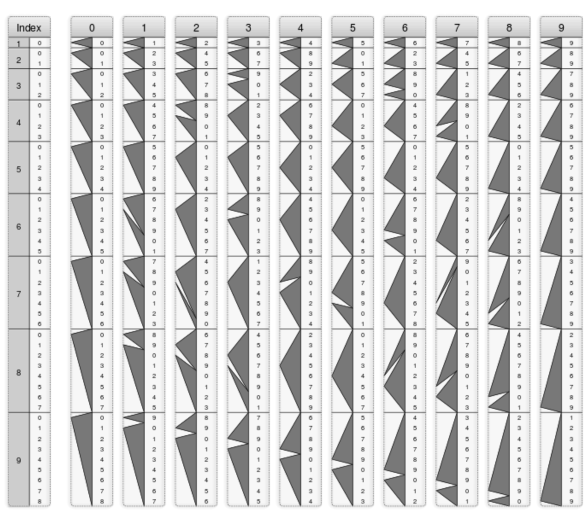
Example

6785 × 8

```
  1 1
  4 5 6 4
+   8 6 4 0
-----------
  5 4 2 8 0
```



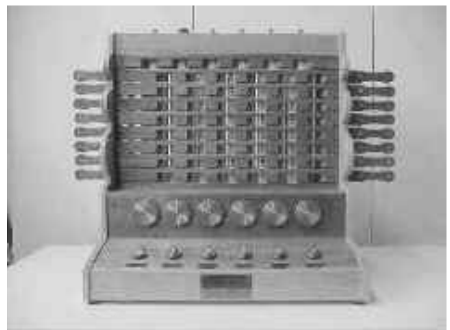
Variant: Genaille–Lucas ruler

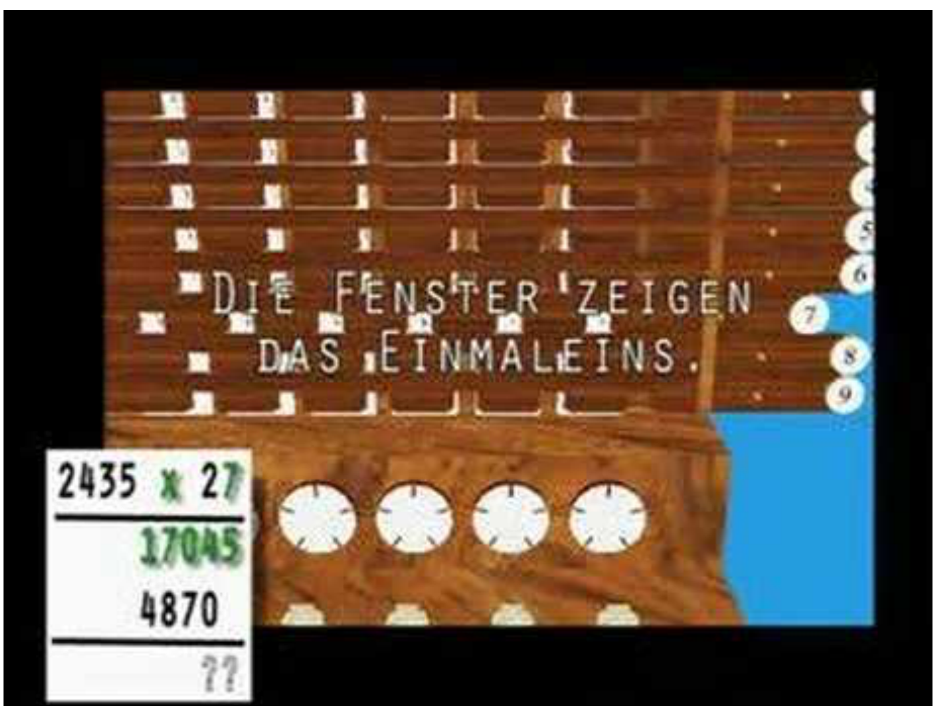


Early Computational Devices

- Schickard's Calculating Clock
  - first mechanical calculator, 1623

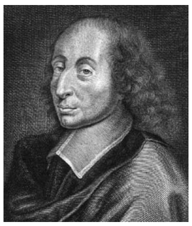
Wilhelm Schickard
1592-1635





Early Computational Devices

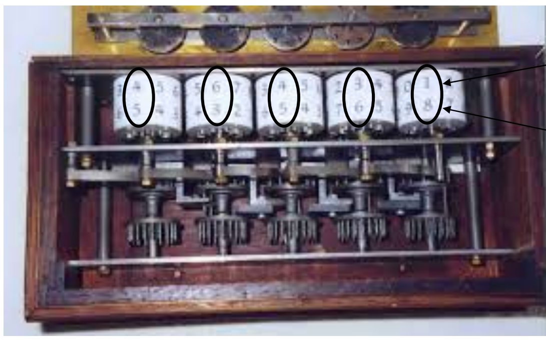
- Pascaline mechanical calculator (adds and "subtracts")



Blaise Pascal
1623-1662

Pascaline: Two Displays

The cover has holes to show one digit per wheel.
A horizontal bar hides one of these two rows of digits.



Number 46431

9's complement 53568

46431
+ 53568
= 99999

9's complement

- Pascaline has two rows of windows to show a number and its 9's complement, one is hidden.
- The 9's complement of a using N digits, denoted $a_{9C}^{(N)}$, is: $a_{9C}^{(N)} = 10^N - 1 - a$
  - Example $15292_{9C}^{(5)} = 99999 - 15292 = 84707$
- Also: $(a_{9C}^{(N)})_{9C}^{(N)} = a$
- $(a\text{-}b)_{9C}^{(N)} = 10^N - 1 - (a\text{-}b)$
  $= 10^N - 1 - a + b = a_{9C}^{(N)} + b$
- $a\text{-}b = (a_{9C}^{(N)} + b)_{9C}^{(N)}$
- To compute $a - b$ (using N digits):
  - Compute the nine's complement of a and then add b.
  - Compute the nine's complement of the result.

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Example

- Compute 292 - 14 using only addition on a Pascaline.

	number	9's comp.
Clear machine.	000000	hidden
Slide bar.	hidden	999999
Set to 292. (*a*)	hidden	000292
Slide bar. (a_{9C})	999707	hidden
Add 14. (a_{9C} + b)	999721	hidden
Slide bar (a_{9C} + b)$_{9C}$	hidden	000278

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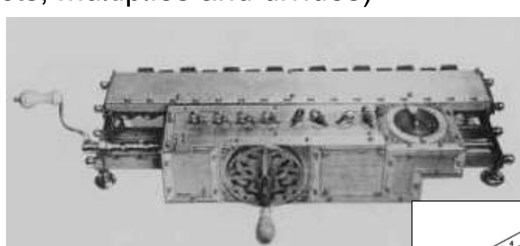
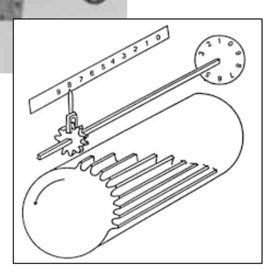
Early Computational Devices

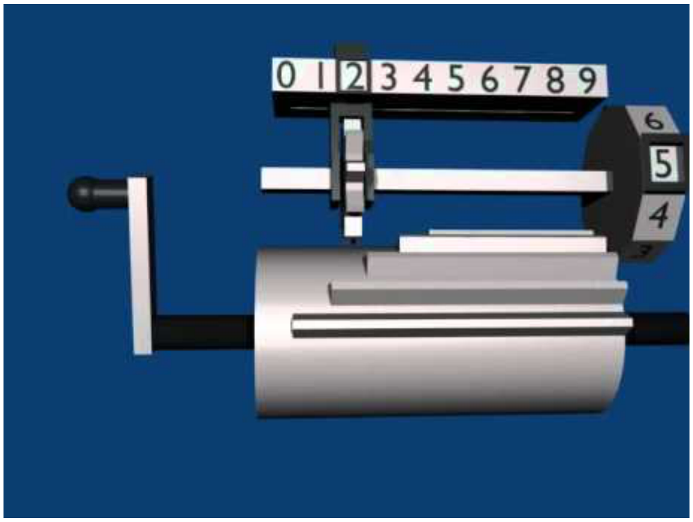
- Leibniz's calculating machine, 1674
  (adds, subtracts, multiplies and divides)

Gottfried Wilhelm von Leibniz
1646-1716

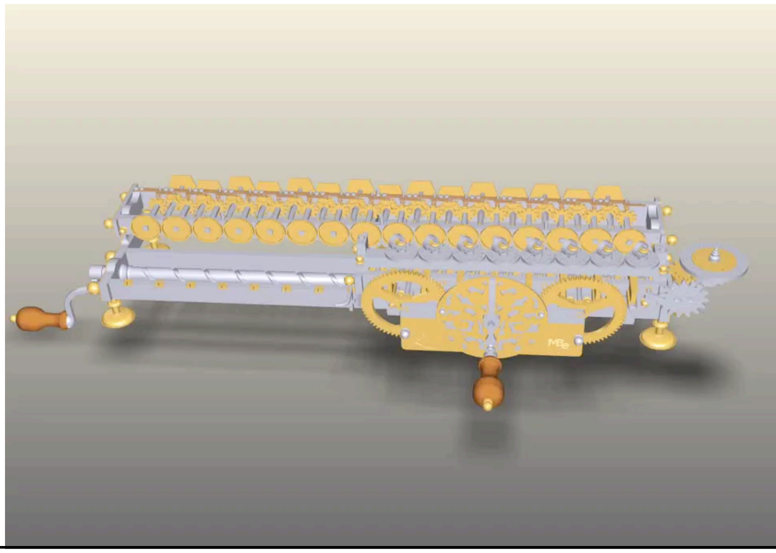




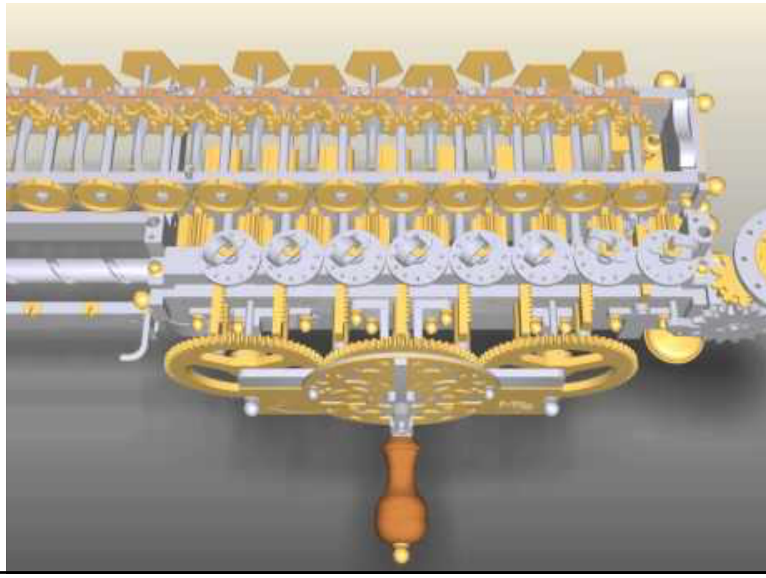
Stepped Drum



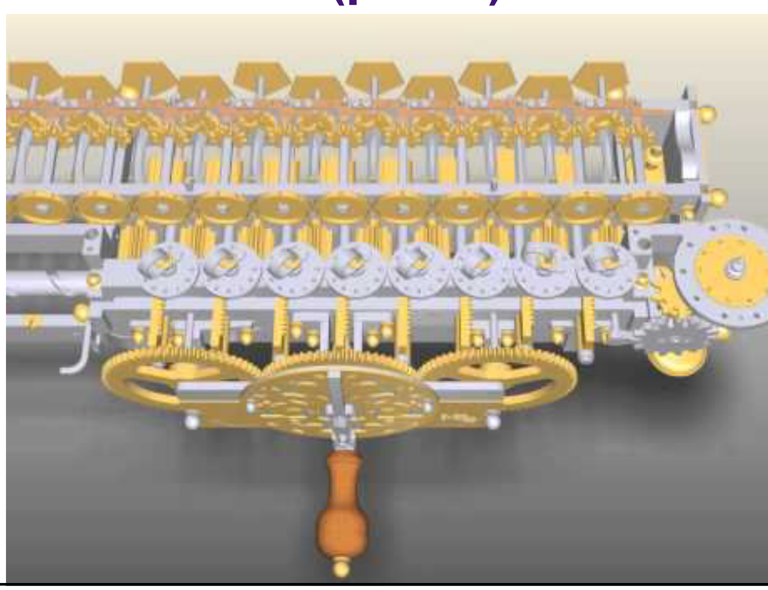
748 + 219



2748 21. (part 1)



2748 21. (part 2)



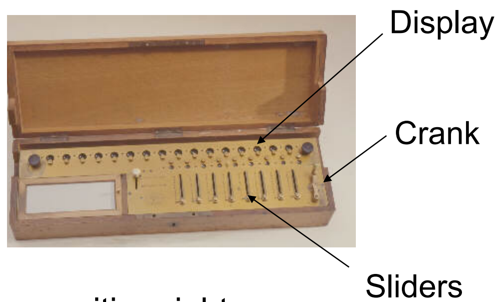
Early Computational Devices

- The calculator became popular in the 1800s.
- Charles Xavier Thomas de Colmar (1785-1870), of France, made the **Arithmometer** based on Leibniz's design in a simple and reliable way.

- Because of its unidirectional drum, division and subtraction required setting a lever.
- A.K.A. the Thomas Machine, it was very successful selling into the first half of the 20th Century, along with numerous clones.

Early Computational Devices

- Thomas Arithmometer, 1820



To multiply
1234 by 21,
clear the machine,
then move sliders
to 1 2 3 4,
then crank once
to get 1234.
Then shift the display one position right
and crank twice to add 12340 twice to get
1234 + 12340 + 12340 = 25914. (requires 3 cranks)

Early Computational Devices

- Comptometer

Dorr Eugene Felt
1862-1930

Early Computational Devices

- Curta (20th Century)
  based on stepped drum principle

Early Computational Devices

- Slide Calculators
  Helped compute approximations for logarithms and exponents, used for centuries

William Oughtred
1574-1660