(Foto: Wilfried Denz, IFHB)

400 years mechanical calculation

from Schickard's *calculating clock* to the electromechanical calculator

Wilfried Denz
Symposium, University of Antwerp
1 Feb. 2025

Contents

400 years mechanical calculation - from Schickard's *calculating clock* to the electromechanical calculator

- **17th + 18th century**: the first calculating machines
- **19th century**: slow start of mass production
- **20th century**: mass production/application and cutting-edge technology
- **1970s**: end of mechanical calculating machines
- discussion

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Wilfried Denz

- since 1989 consultant in corporate environmental protection
- since 2000 collector of mechanical calculating devices/machines: www.rechnen-ohne-strom.de
- active member of associations for the history of technology

  FORUM INDUSTRIE KULTUR e.V.

  https://forum-industriekultur.de
- IG Technikgeschichte of

  VDI
- and…

Small section from collection of Wilfried Denz

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Member of

IFHB e.V.

Internationales Forum Historische Bürowelt

founded in 1981
around 335 members
from over 20 countries

since 2022 **editor** of the IFHB magazine Historische Bürowelt

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17th century

Gottfried Wilhelm Leibniz, 1671-94: *living calculating bank*

Replica in HNF (Foto: Jan Braun, HNF)

- The world's first **4-species calculating machine: + - ∗ ÷**
- Principle: **stepped drums**
- Sketches of the **pinwheel** and a **mechanical binary calculator**

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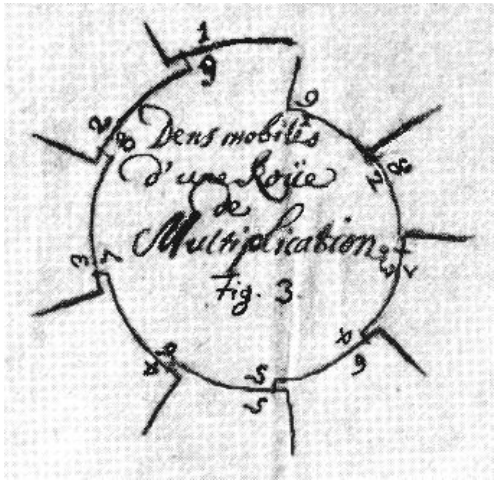
17th century

Gottfried Wilhelm Leibniz
1671 to Herzog Johann Friedrich:

„It is unworthy for a man of high intellect to waste his time with slavish arithmetic, because with a machine any semi-skilled person could do the maths safely.“

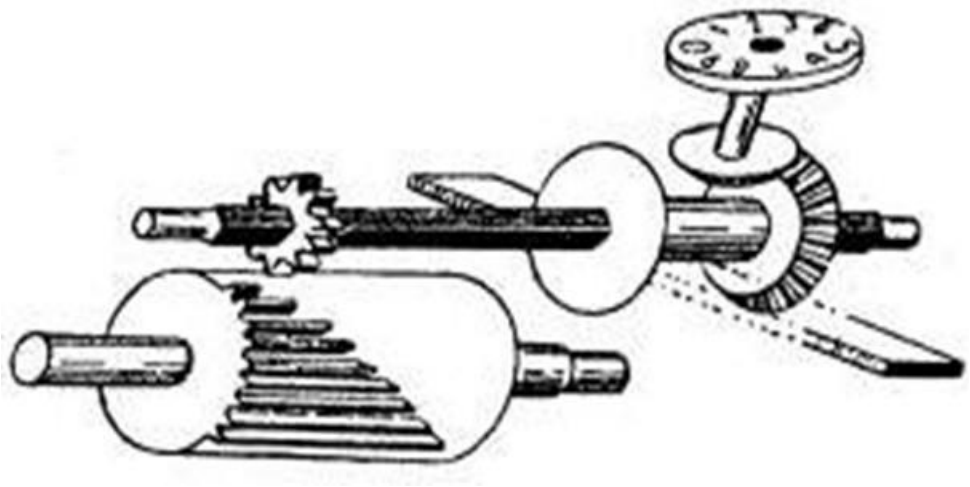
Source: https://blog.hnf.de/herr-leibniz-und-seine-logik/



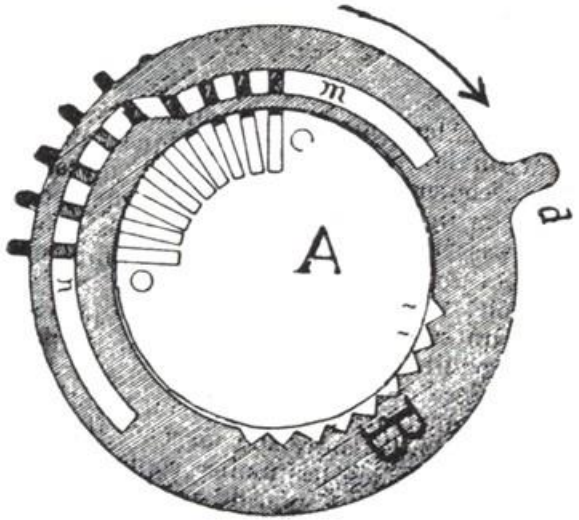
Dens mobilis (pinwheel); Hand sketch by Leibniz

stepped drum and pinwheel

stepped drum



pinwheel



other systems:
click wheel drive, adapting segment, proportional gear ……

pictures: Martin „Die Rechenmaschinen“, 1925

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17th century

Blaise Pascal:

„The calculating machine produces effects that come closer to thinking than anything that animals do; but it achieves nothing that could lead to the statement that it has will powers like animals.“

(from „Pensées sur la religion et sur quelques autres sujets“)

***Pascaline* 1642 –**
calculating machine only for addition
about 50 machines were produced
5-12 decimal places
decadic and for French + British currency

Source: https://blog.hnf.de/herr-leibniz-und-die-erfindung-der-rechenmaschine/

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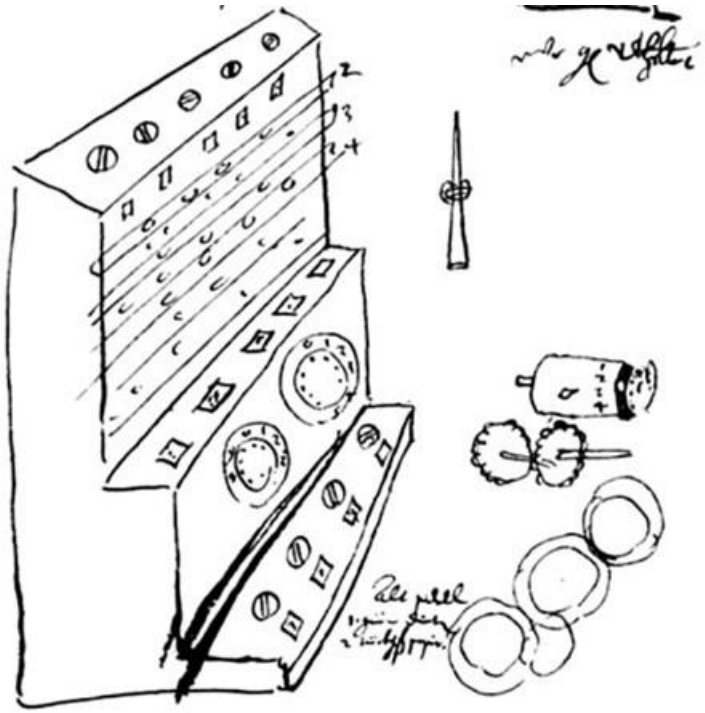
17th century - **the world's first calculating machine**

1623 Wilhelm Schickard
letter to Johannes Kepler:



„Stuttgarter-Skizze“ from Schickard
location: Württembergische Landesbibliothek, Stuttgart

„I recently tried to do the same thing mechanically that you did mathematically and built a ... machine that automatically adds, subtracts, multiplies and divides given numbers at a glance.

You would laugh out loud if you were there and witnessed ***how it automatically increases the digits to the left as often as it goes over a tens or hundreds*** *or takes something away from them when subtracting."*

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Definition of calculating machine

Calculating machine =
machine which can perform one to all four basic arithmetic operations and which has an automatic transfer of tens.

Abacus and slide adders are therefore no calculating machines.

Schickard's calculating machine consisted of a **disc calculator** for addition and subtraction with a multiplication aid based on the **Napier calculating rods** and a **memory register**.

Schickards *calculating clock* 1623

Replica in HNF

(Foto: Jan Braun, HNF)

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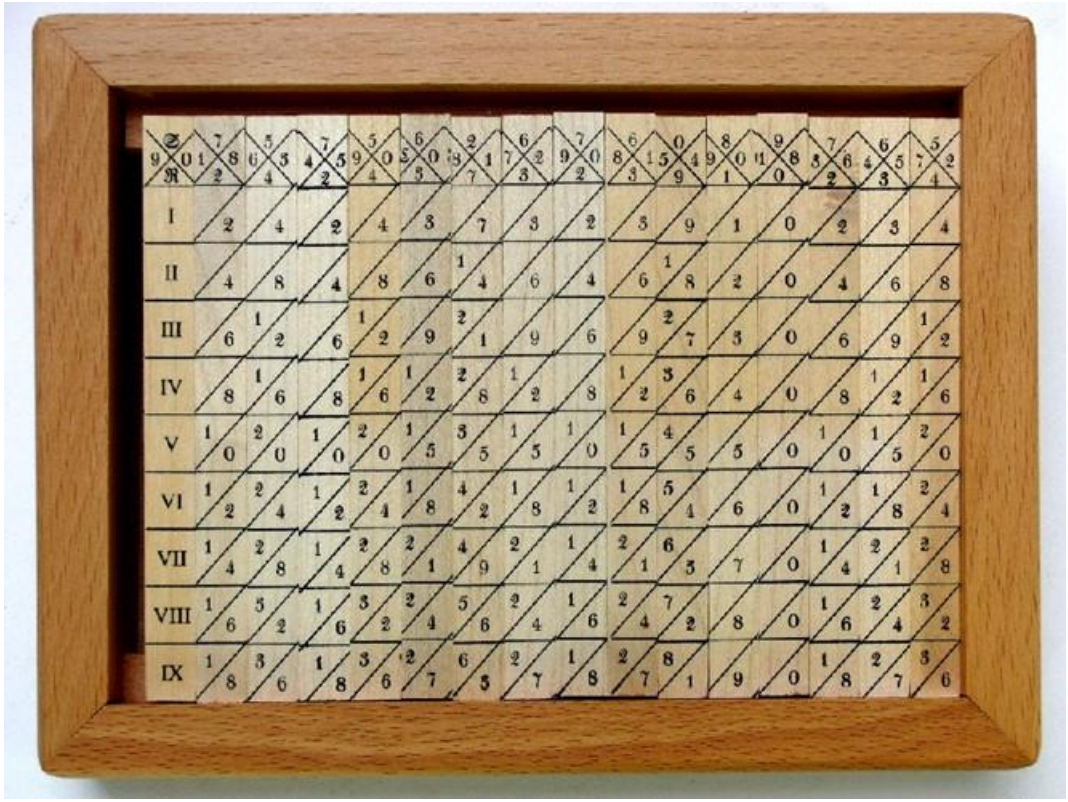
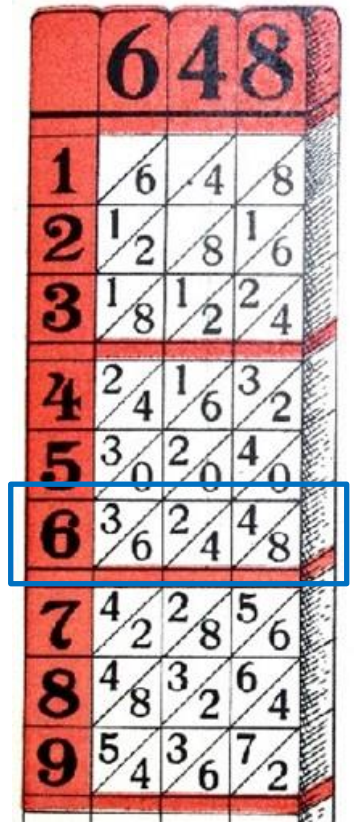
Early calculating aid – from 1617

1x1-calculating rods from Napier (Neper)



(Fotos: Wilfried Denz, IFHB)

6 x 648 =



= 3(6+2)(4+4)8 = 3888

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17th century - **the world's first calculating machine**

Wilhelm Schickard (1592-1635)

- 1619 Professor of Hebrew at the University of Tübingen
- From 1631 also professor of astronomy, geodesy and mathematics
- developed the astroscopium and graphical methods for calculating eclipses and for calculations in the Copernican system.
- Astronomer Johannes Kepler came to Tübingen in 1617/20 to defend his mother in a witch trial.
- They had been in close scientific dialogue ever since. Kepler called him a ‘two-handed philosopher’.

Schickard with Tellurium

Source: https://commons.wikimedia.org/wiki/ File:C_Melperger_-_Wilhelm_Schickard_1632.jpg

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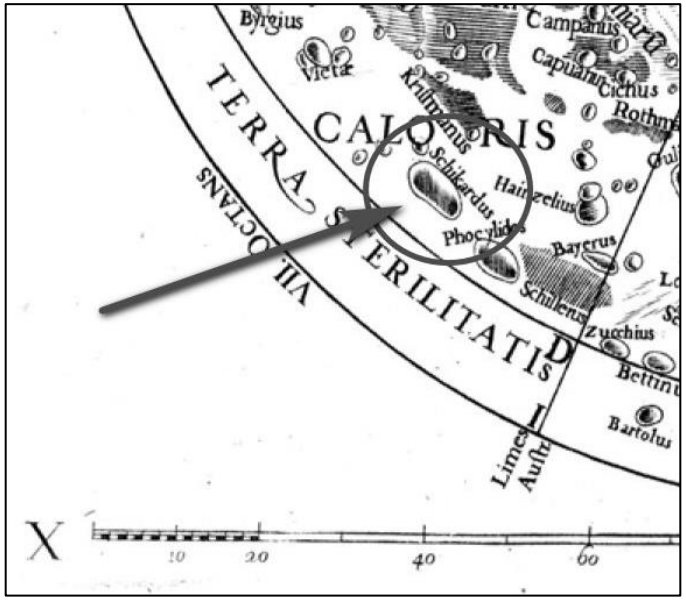
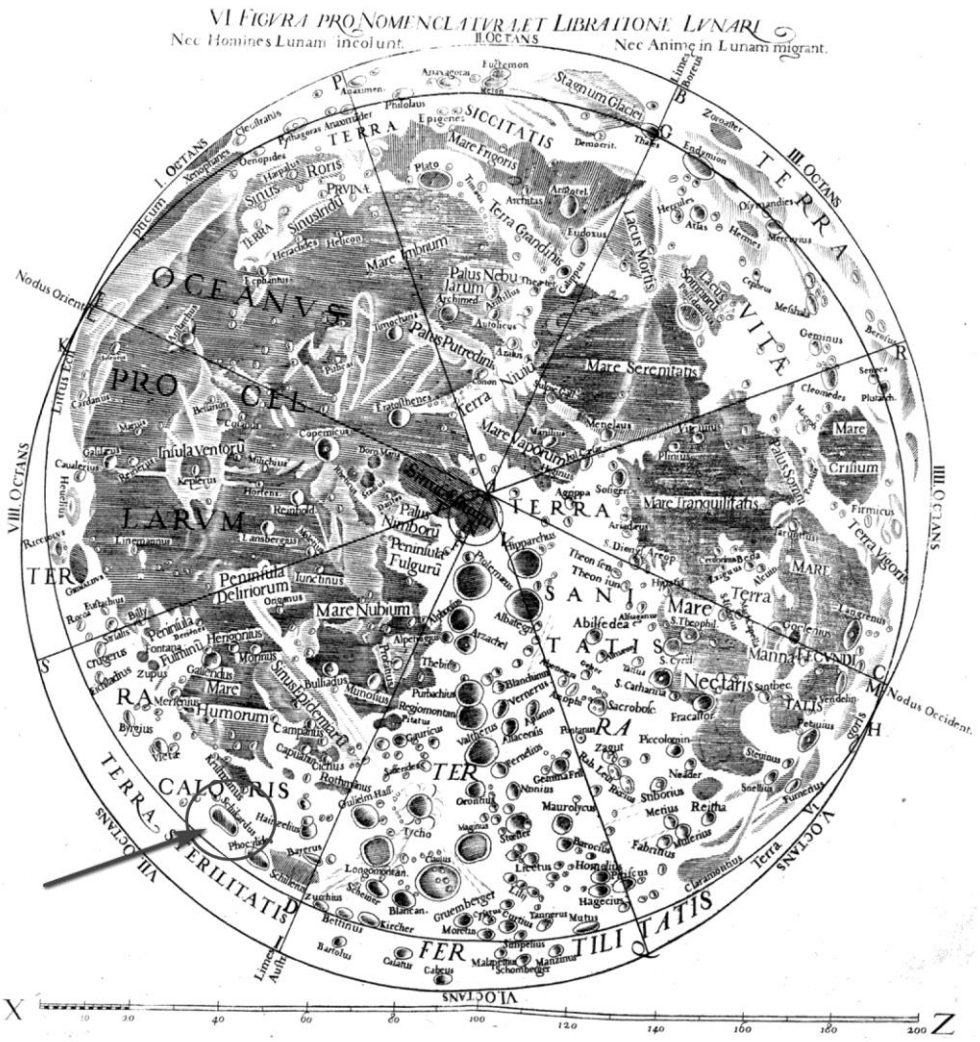
17th century - **the world's first calculating machine**

Moon crater „Schickard“

Moon map by Riccioli, 1651

Acknowledged by IAU in 1935





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17th century

Scientific revolution in early modern Europe with many inventions - examples include arithmetic:

- 1617: calculating rods by John Napier (1x1 on sticks)
- 1623: Schickard's calculating clock
- 1624: logarithmic scale + dividers by Edmund Gunter
- 1632/33: logarithmic disc/slide rule by William Oughtred
- 1642: Pascaline (adding machine)
- 1666: disc adder and Napier multiplier by Sam Moorland
- 1671/94: Leibniz 4-species calculating machine
- …

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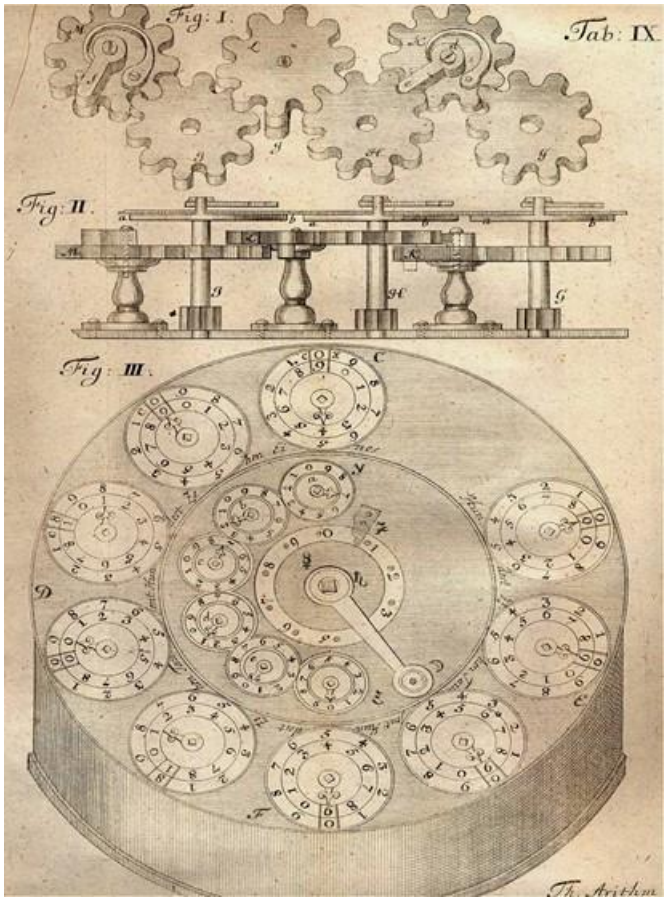
Calculating machines: error-free

Jacob Leupold in „Theatrum arithmetico-geometricum“ 1727:

„And although in arithmetic the calculating machines may seem to many to be something superfluous and not very useful ...

They may well consider, on the other hand, that such machines never make mistakes in the operation of calculating ...“

The Author‘s calculating machine (adapting segment)



(source: Leupold ebd.)

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18th century

Calculating machines - mostly unique pieces **for personal use** or for '**cabinets of curiosities**' (examples):

Calculating machine by Johann Helfrich Müller (1784, stepped drum, replica HNF)

(Foto: Jan Braun, HNF)

Arithmetic machine by Reichold (1792, click wheel, replica Lewin/Wolff, IFHB)

(Foto: Michael Lewin, Ullrich Wolff, HBw 124)

19th century – stepped drum

Arithmomètre by Charles Xavier Thomas de Colmar, 1820:

Arithmometer for King Ferdinand II of Portugal; 1852

(Foto: Jan Braun, HNF)

- patented 1820 (stepped drum)
- start of ‘series production’ in 1852
- around 1,500 pieces until 1878 (≙ 1 piece per week)
- from 1885: Burkhardt arithmometers in Glashütte, Germany

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19th century - pinwheel

Odhner 1878: first marketable pinwheel calculating machine

Odhner Prototype, 1874

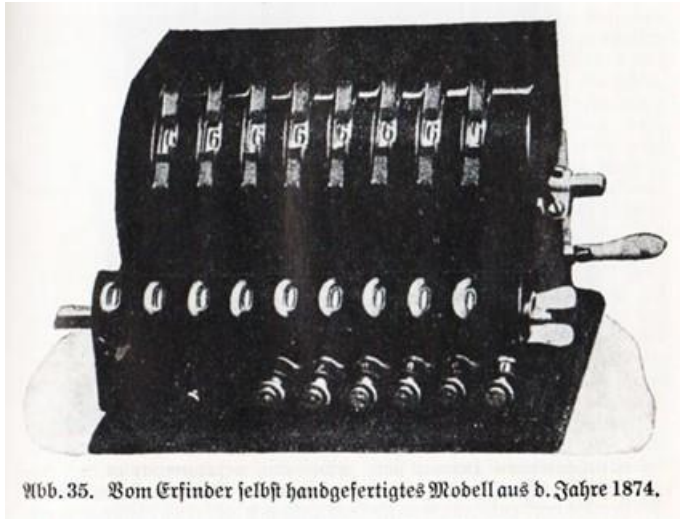
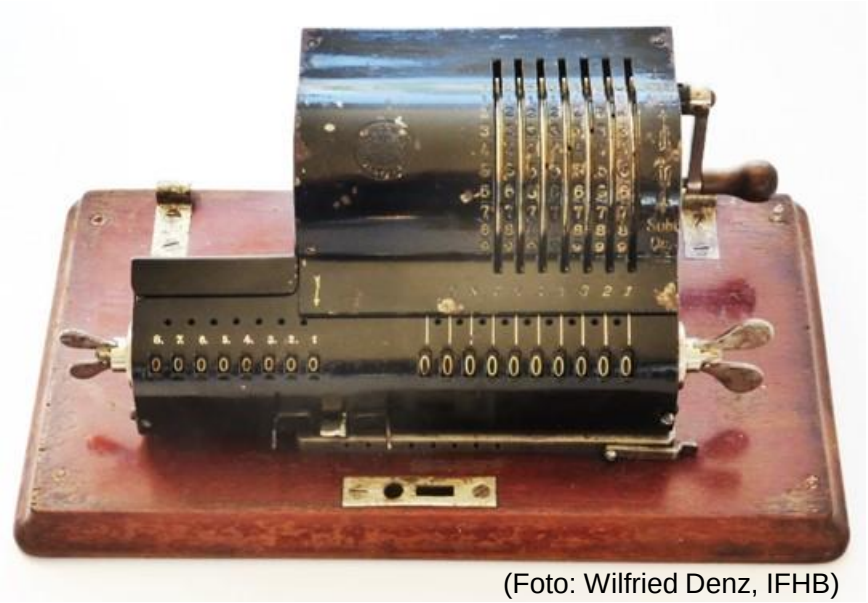


Abb. 35. Vom Erfinder selbst handgefertigtes Modell aus d. Jahre 1874.

(Quelle: Martin „Die Rechenmaschinen“, 1925)

Brunsviga C short crank, ca. 1900



(Foto: Wilfried Denz, IFHB)

- Odhner until 1917 St. Petersburg, then Sweden
- from 1892 production in Germany by GNC/Brunsviga
- subsequently many other manufacturers in Europe and worldwide

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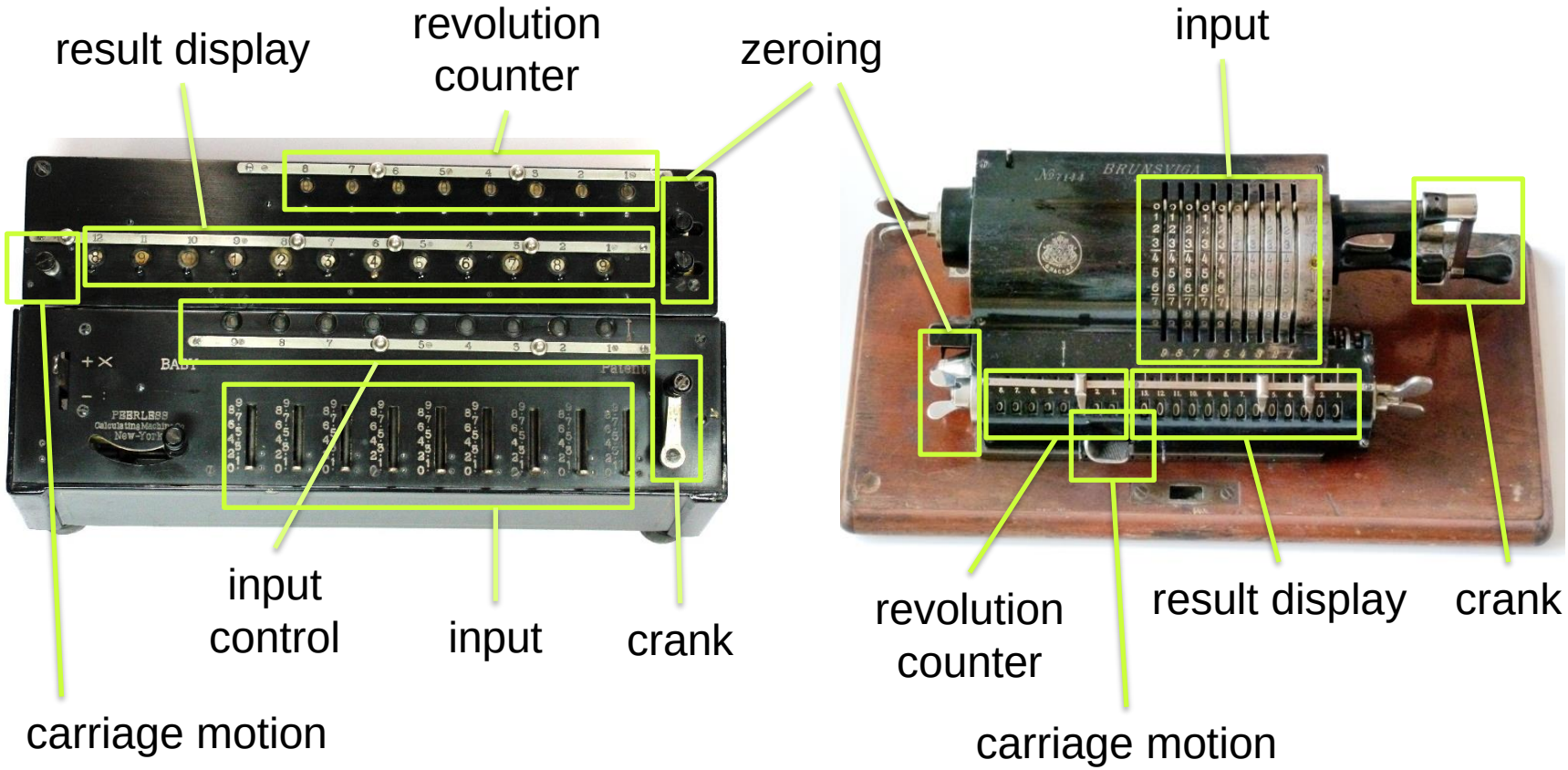
4-species calculating machine:

Operating and readout units



(Fotos: Wilfried Denz, IFHB)

volume development of calculing machines

R. Mehmke in „Numerisches Rechnen“, 1902:

- **1800**: ca. **15 constructions** and around **70 machines** built globally
- **1900**: ‘**120** constructions’ and ‘**4,000 machines** built’ in Europe

Later in Europe (similar in USA):

- around **1920 many 10,000** in use
- In the **1950s over one/few million**

At the beginning very high price:
1900-1920: about half the annual salary of a middle-ranking employee

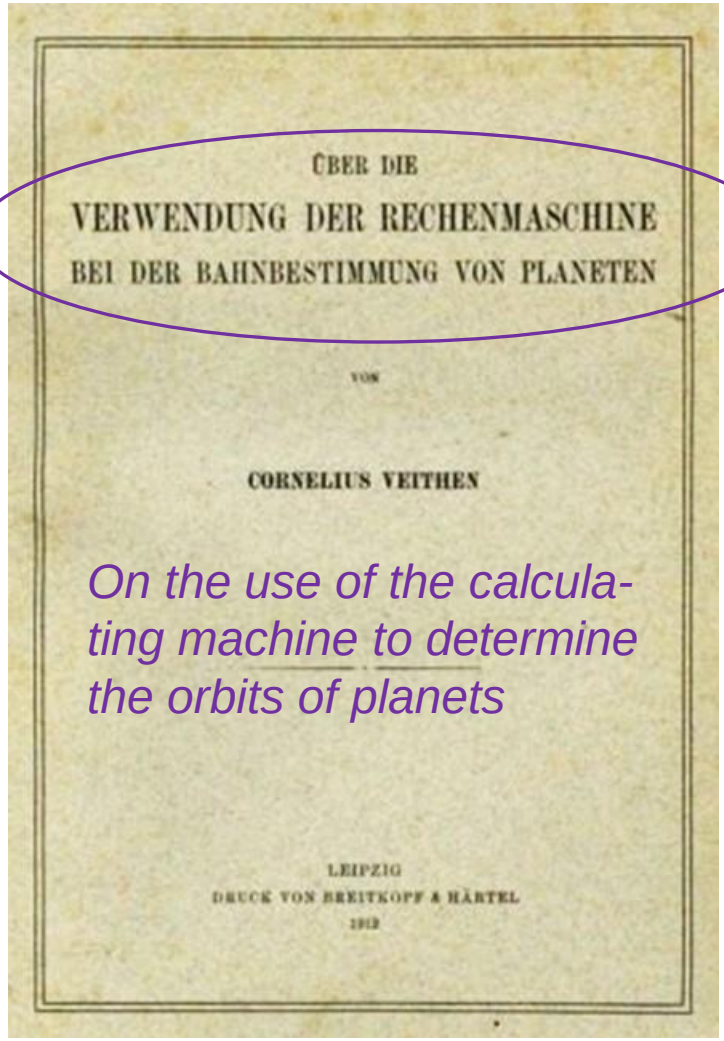
First users: insurance companies, financial institutions, surveying offices, statistical offices (also punched cards, USA), commercial offices, payroll offices, technical offices, universities/research institutes

Measures: Increase of calculating machines

Sales argument **time saving**

Many studies on time savings

- E.g. PhD by Cornelius Veithen, 1912:
  „*… less mental effort, more certainty of calculation, ¼ time saving …*'
  compared to logarithmic calculation
- Model name *TIM - Time is Money*


ÜBER DIE
VERWENDUNG DER RECHENMASCHINE
BEI DER BAHNBESTIMMUNG VON PLANETEN
VON
CORNELIUS VEITHEN
On the use of the calculating machine to determine the orbits of planets
LEIPZIG
DRUCK VON BREITKOPF & HÄRTEL
1912

(Fotos: Wilfried Denz, IFHB)

Measures: Increase of calculating machines

Sales argument

Error-free and safely - always correct results

- see Leupold above:
  '... **never makes mistakes** in calculation of the example ...'
- *Mercedes-Euklid* advert: 'Anyone who has a lot to calculate and does not use modern tools is wasting their health and energy, their time and money, and **exposing themselves to errors and losses**.'
- *Optima* disc adding machine: '... calculates automatically and quickly, and **eliminates errors** and mental effort.'

Discussion: wrong incorrect/insufficient, over-spinning, ...

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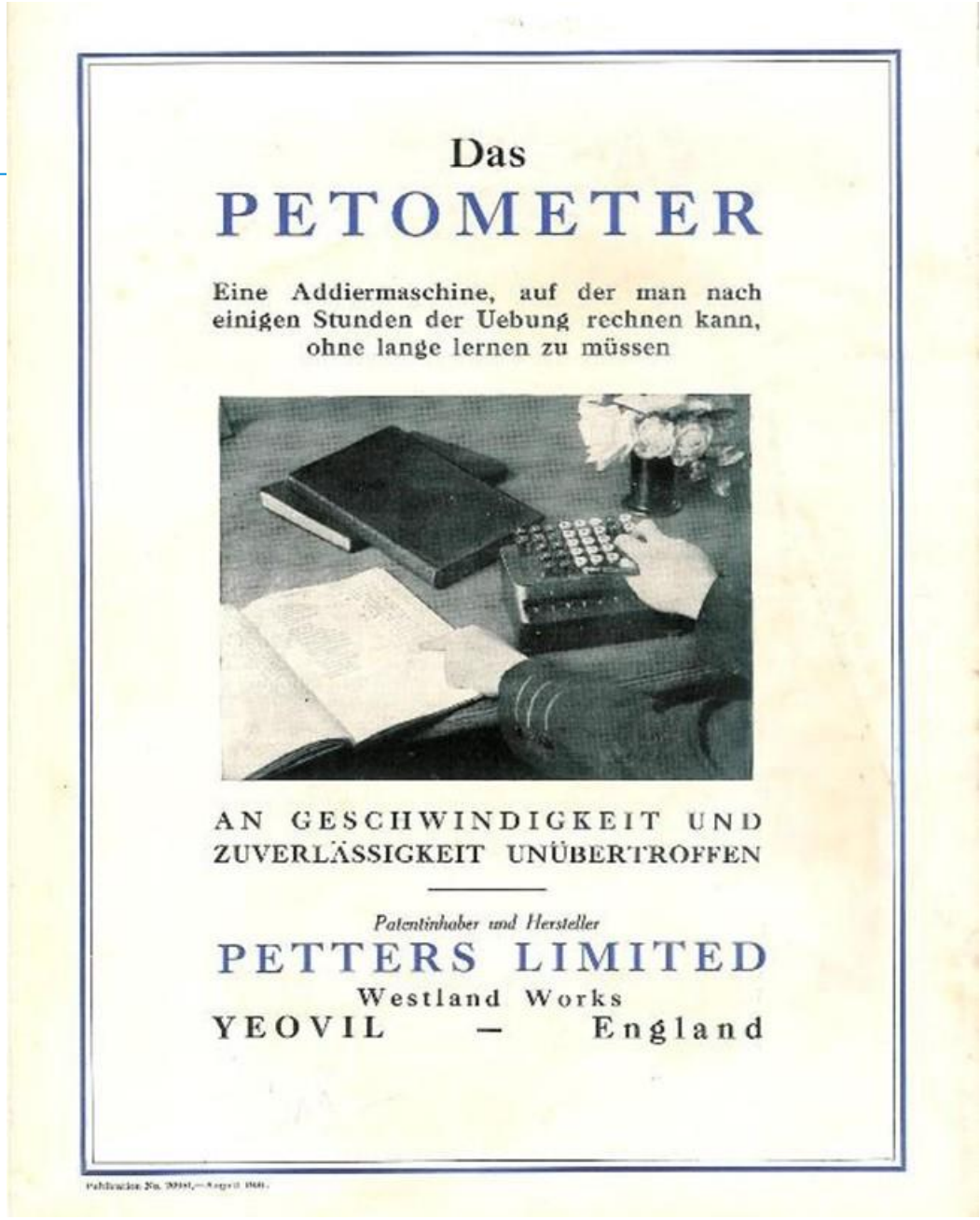
Measures

Sales argument *simple*

E.g. *Petometer*:

„An adding machine on which you can calculate after a few hours of practice without having to learn for a long time. Unequalled in speed and reliability. “

Conclusion:
Simple
Fast
Error-free



(Foto: Wilfried Denz, IFHB)

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volume development: Important role of Brunsviga

Brunsviga was a major driver of demand in Europe!

- Large network of dealers and representatives
- they were specially trained for applications in various industries
- this enabled quick demonstration of the respective tasks: possible cost savings became obvious
- development of algorithms (see below)
- active advertising, e.g. Brunsviga monthly magazine
- many technical innovations by Franz Trinks

Brunsviga 13 RK
(Fotos: Heidersberger)

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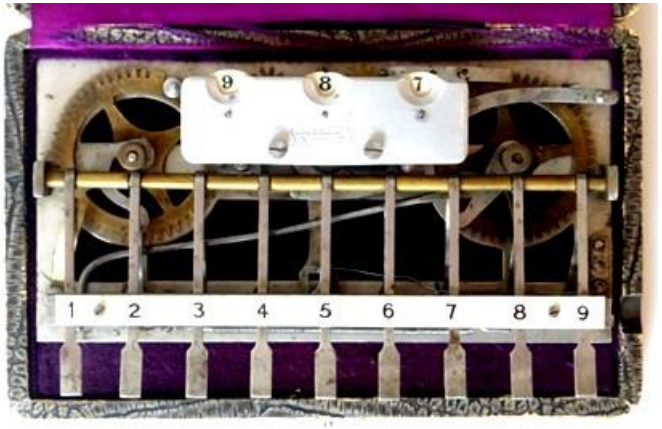
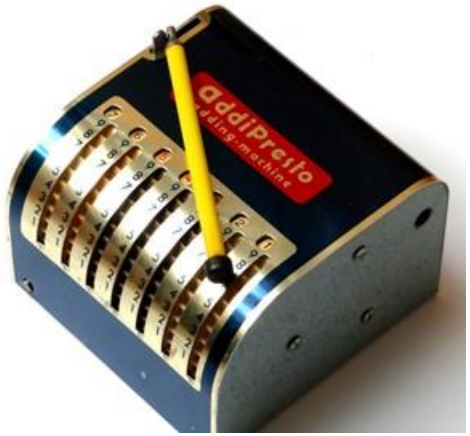
diversification from 1900

Adding machines: column and other small adders





column, counting wheel, rack and disc adders

(Fotos: Wilfried Denz, IFHB)

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diversification

Adding machines: half and full keyboard, often with printing unit

Torpedo 1930s

Very fast:
no crank/lever movement
parallel key input possible

Comptometer from 1887

(Fotos: Wilfried Denz, IFHB)

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using adding machines

Using full-keyboard adding machines in a tax office

Fig.: Los Angeles County Tax Collecting Office with 90 *Comptometers* in two-shift operation in the mid-1930s

(Source: Felt & Tarrant Manufacturing Co.: Comptometer News, Vol. 8, Nr. 1 Februar, 1936)

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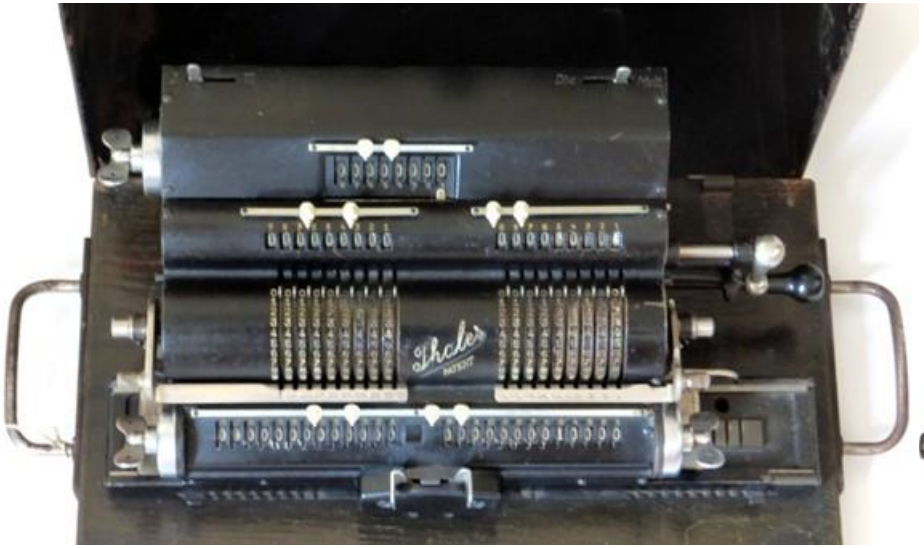
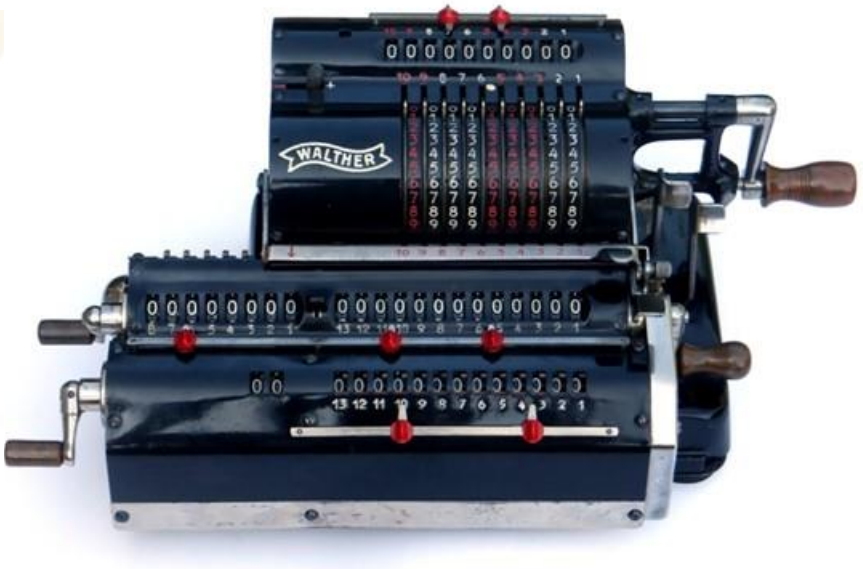
diversification

specialised calculating machines



Thales GEO



Walther SMKZ with memory

specialised models, e.g.
twin calculators for geodetic calculations
or calculators with a memory register

(Foto: Wilfried Denz, IFHB)

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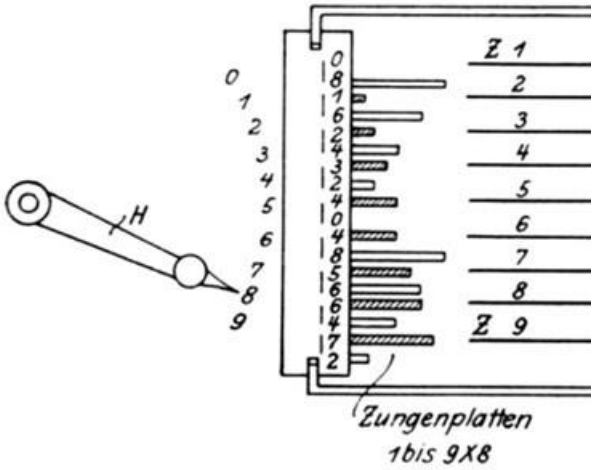
diversification

specialised calculating machines



Millionaire by Hans W. Egli, Zurich; 1899-1930er

Specialised model *Millionaire* for direct multiplication using multiplication bodies:
only one crank rotation for multiplication with 1-9

(Foto: Wilfried Denz, IFHB; Image source right: Prometheus 1911)

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New algorithms

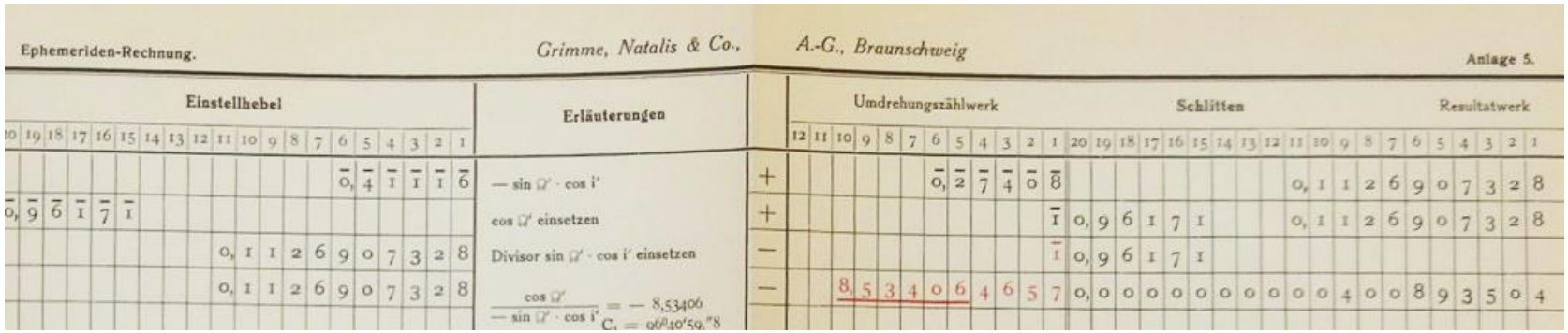
Numerics for calculating machines

Numericists such as Runge, Willers and Walther promoted the use of calculators by developing reliable algorithms, e.g.

- for land surveyors to calculate the coordinates of polygon points for the resection method or
- for astronomical positioning

Example from '*Calculating with the patented Trinks-Brunsviga calculating machine*', 1921: Ephemeris calculation (astronomy)

(Foto: Wilfried Denz, IFHB)



Input lever | Formula | Revolution counter | Intermediate result

Crank rotation

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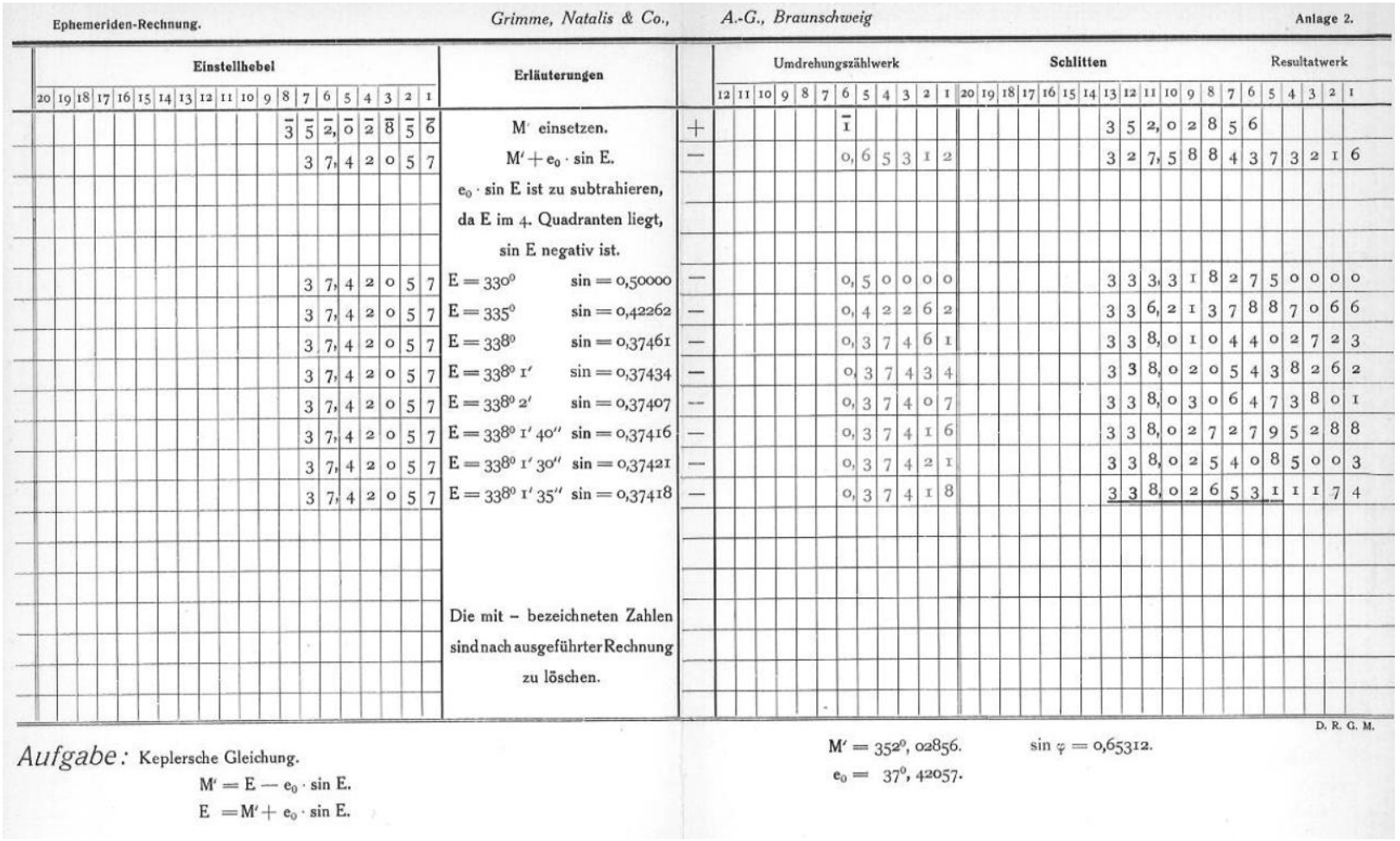
New algorithms

Ibid.: Algorithm for Kepler's equation



Ephemeriden-Rechnung. — Grimme, Natalis & Co., A.-G., Braunschweig — Anlage 2.

Einstellhebel | Erläuterungen | Umdrehungszählwerk | Schlitten | Resultatwerk

	Einstellhebel	Erläuterungen	Umdrehungszählwerk	Schlitten	Resultatwerk
		M' einsetzen.	+		352,02856
	37,4205 7	$M' + e_0 \cdot \sin E$.	−	0,653 12	32 7,588 43 7 3 2 1 6
		$e_0 \cdot \sin E$ ist zu subtrahieren, da E im 4. Quadranten liegt, sin E negativ ist.			
	37,4205 7	$E = 330^0$ $\sin = 0{,}50000$	−	0,500000	33 3,318 27 5 0 0 0 0
	37,4205 7	$E = 335^0$ $\sin = 0{,}42262$	−	0,422622	33 6,211 37 8 8 7 0 6 6
	37,4205 7	$E = 338^0$ $\sin = 0{,}37461$	−	0,374611	33 8,011 04 4 0 2 7 2 3
	37,4205 7	$E = 338^0\ 1'$ $\sin = 0{,}37434$	−	0,374343	33 8,020 54 3 8 2 6 2
	37,4205 7	$E = 338^0\ 2'$ $\sin = 0{,}37407$	−	0,374074	33 8,030 67 3 8 0 1
	37,4205 7	$E = 338^0\ 1'\ 40''$ $\sin = 0{,}37416$	−	0,374161	33 8,027 27 9 5 2 8 8
	37,4205 7	$E = 338^0\ 1'\ 30''$ $\sin = 0{,}37421$	−	0,374212	33 8,025 40 8 5 0 0 3
	37,4205 7	$E = 338^0\ 1'\ 35''$ $\sin = 0{,}37418$	−	0,374188	33 8,026 53 1 1 1 7 4
		Die mit − bezeichneten Zahlen sind nach ausgeführter Rechnung zu löschen.			

D. R. G. M.

Aufgabe: Keplersche Gleichung.

$M' = E - e_0 \cdot \sin E$.

$E = M' + e_0 \cdot \sin E$.

$M' = 352^0, 02856.$ $\sin \varphi = 0{,}65312.$

$e_0 = 37^0, 42057.$

(Source: https://rechnerlexikon.de/files/BrunsvigaTriplex-Astronomische.pdf)

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High-End 1930s/40s

Programmed, automatic, iterative calculation

Institute for Practical Mathematics, TU Darmstadt, Prof. Walther
(quasi computer centre, service for industry):

- by punch card machines:
  e.g. calculation of steel strength or ‘calculation of critical speeds of a turbine shaft with multiple bearings’
- or with a lot of staff:
  ‘up to 70 young ladies were employed on mechanical manual calculating machines with iterative calculation tasks to be solved.
  ... a kind of ‘human-powered’ parallel computer.’
- or by …

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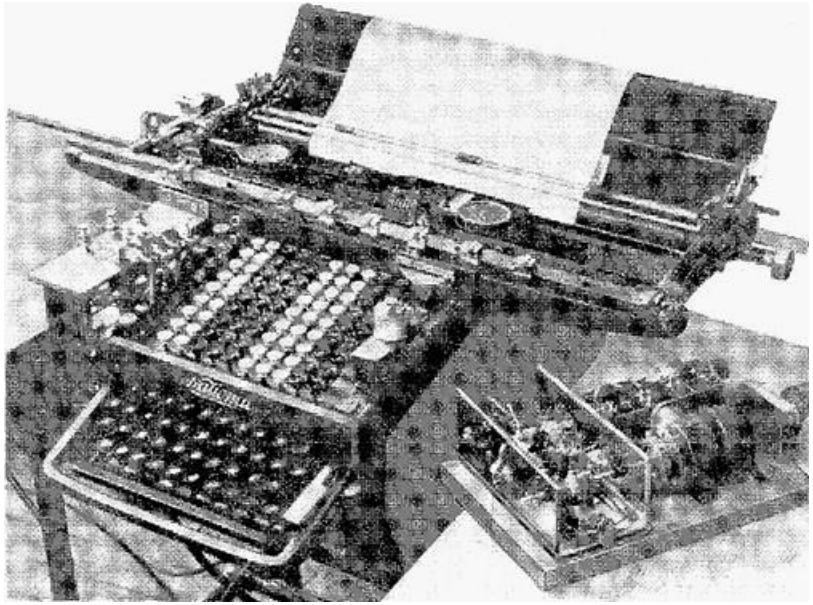
High-End 1930s/40s

Programmed, automatic, iterative calculation

Das Institut für Praktische Mathematik der TH Darmstadt (IPM) (Prof. Dr. *A. Walther* mit *H.-J. Dreyer* und *W. de Beauclair*) baute 1943 bis 1944 zwei elektrische Programmsteuerungen (eine mit umlaufender Kontaktwalze, eine zweite mit Drehwähler und Stecktafel) zur Buchungsmaschine National 3000 zum Zwecke der selbsttätigen Errechnung von Zwischenwerten in weitmaschig vorliegenden Funktionstabellen. Ferner plante es die Verkopplung von Fernschreib- und Lochkartenmaschinen und deren Programmsteuerung mittels Lochstreifen zu einem Rechenautomaten, kam aber über die Vorarbeiten nicht hinaus.



Source: „Taschenbuch der Informatik: Band I: Grundlagen der technischen Informatik“; Steinbuch, Weber

National 3000
with programming unit

Development of these ‘mechanical computers’ terminated by Zuse, ENIAC et al.

Source: „Alwin Walther, IPM, and the Development of Calculator/ Computer Technology in Germany, 1930-1945”, W. de Beauclair, 1986

Cutting-edge 1950s/60s

Precision mechanics + fully automatic calculators

(Foto: Wilfried Denz, IFHB)

(Foto: Bruno Reich, HBw131)

CURTA I+II
A marvel of precision engineering
1948-1970, 140.000 Units

Rheinmetall SAR IIc
‚Superautomat with Backtransfer‘
1951-1971

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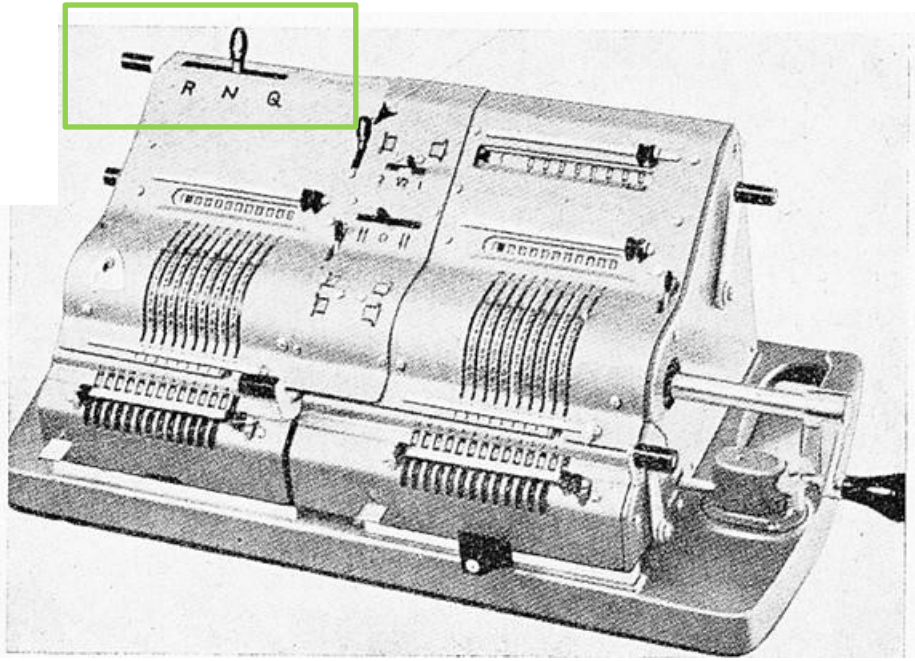
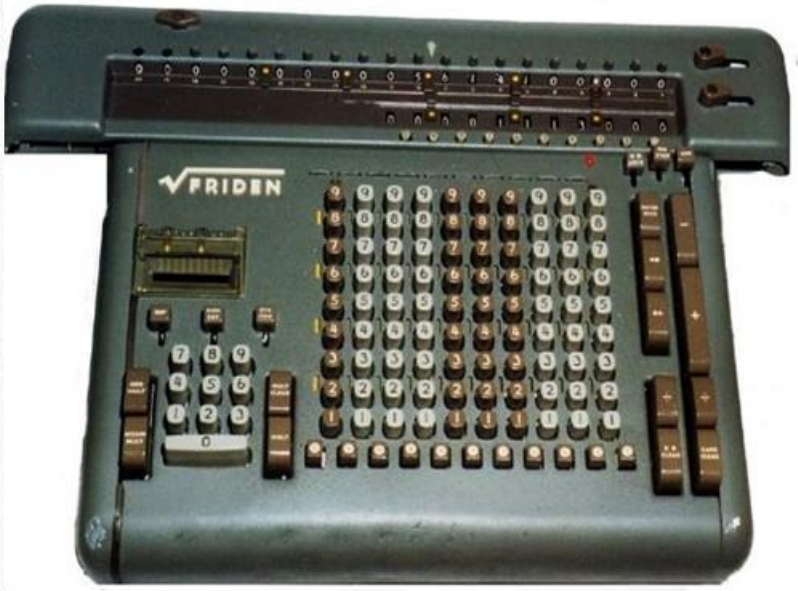
High-End 1950s/60s

Square root automatic



(Quelle: Vermessungstechnische Rundschau 1958)

Brunsviga twin calculating machine
with *Faber-Radizierautomatik*, 1958



(Foto: Jan Braun, HNF)

Friden SRW
square root machine, 1953-1966

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the beginning of the end ...

„Anita Mk VII“ 1961 – First electronic desktop calculator

- The first electronic desktop calculator came onto the market in 1961: the ‘Anita’ from the ‘Bell Punch Company (GB)’ had **144 electron tubes** and could (only) perform the four basic arithmetic operations. At DM 4,200, this calculator cost as much as a VW Beetle..
- In 1964, the ‘IME 84’ from Italy appeared with **transistors** only.

(Source: https://www.hnf.de/dauerausstellung/ausstellungsbereiche/computer-in-wirtschaft-und-beruf-1970-1980/tisch-und-taschenrechner-elektronik-als-massenware.html
Foto: Jan Braun, HNF)

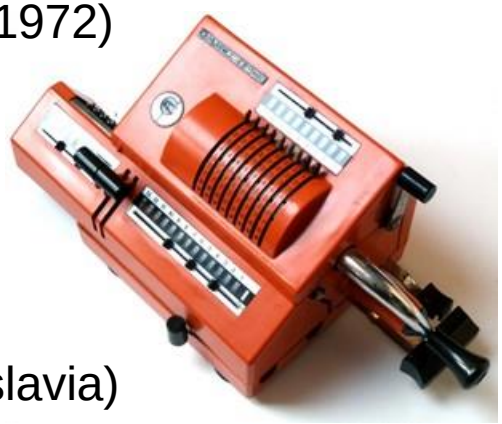
***Anita** Mk VII:*
"A New Inspiration to Arithmetic"

Last, unsuccessful attempts - around 1970

Plastic and block keyboard

finess – completely made of plastic easy to dismantle(1972)

Olympia RT4 – pinwheel-calculator with block keyboard (1969-1972)



Calcorex 403 – Plastic body in fashionable colour (1972-1977, Yugoslavia)

(Fotos: Wilfried Denz, IFHB)

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Links and further information (german/engl.)

- www.ifhb.de - lots of information for IFHB-members
- www.rechnerlexikon.de - wikipedia-style
- www.arithmeum.uni-bonn.de - Museum in Bonn
- www.hnf.de - Museum in Paderborn (de, en, fr, nl)

- Contact:
  Wilfried Denz - w.denz@posteo.de - www.rechnen-ohne-strom.de

On the use/effect of mechanical calculator technology (german):

- *„Stahlgehirne: Mechanische Rechenmaschinen als eine neue Form von Technik (ca. 1850-1930)“* von Jasmin Ramm-Ernst, 2015
- „*Mechanische Rechenmaschinen für wissenschaftliche Berechnungen*“ von Erhard Anthes (2005); http://rechnerlexikon.de/artikel/Mechanische_Rechenmaschinen_für_wissenschaftliche_Berechnungen

(Image)Sources: see respective sheet