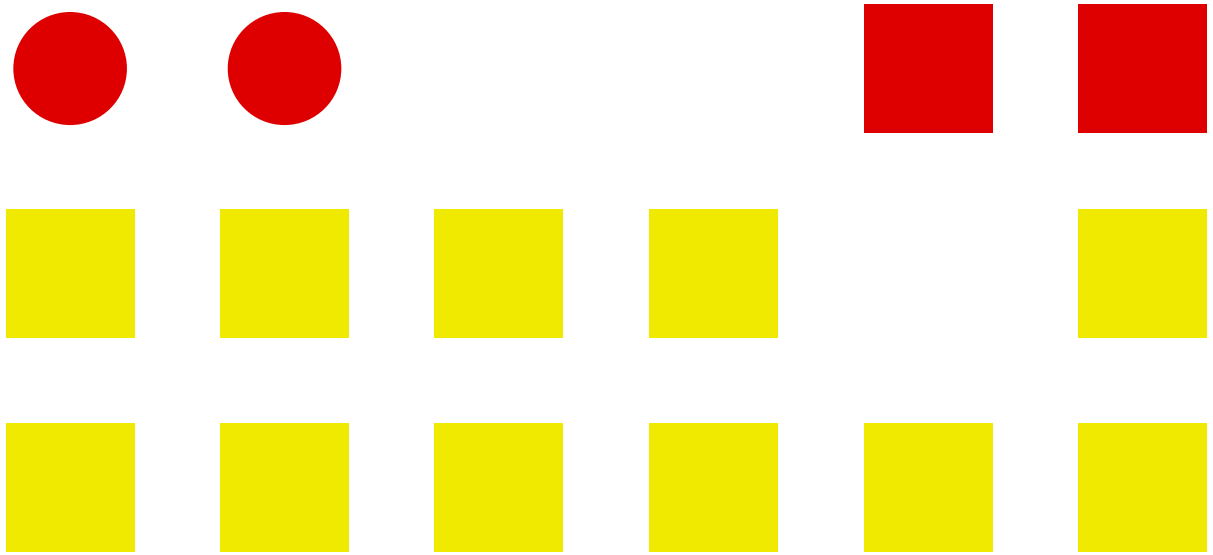


GOING OUT WITH A ROAR

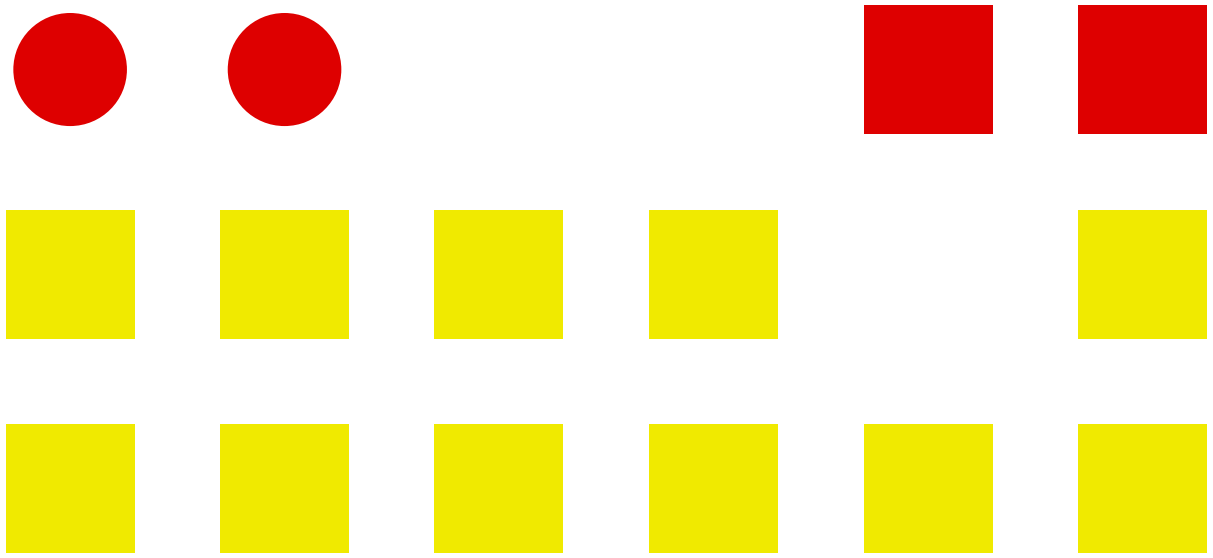
Royal Precision's RPC-4000 – drum computers past their prime

Vintage Computer Festival Zürich
24. November 2018

Jürgen Müller, Hamburg
juergen@e-basteln.de
www.e-basteln.de

CONTENT

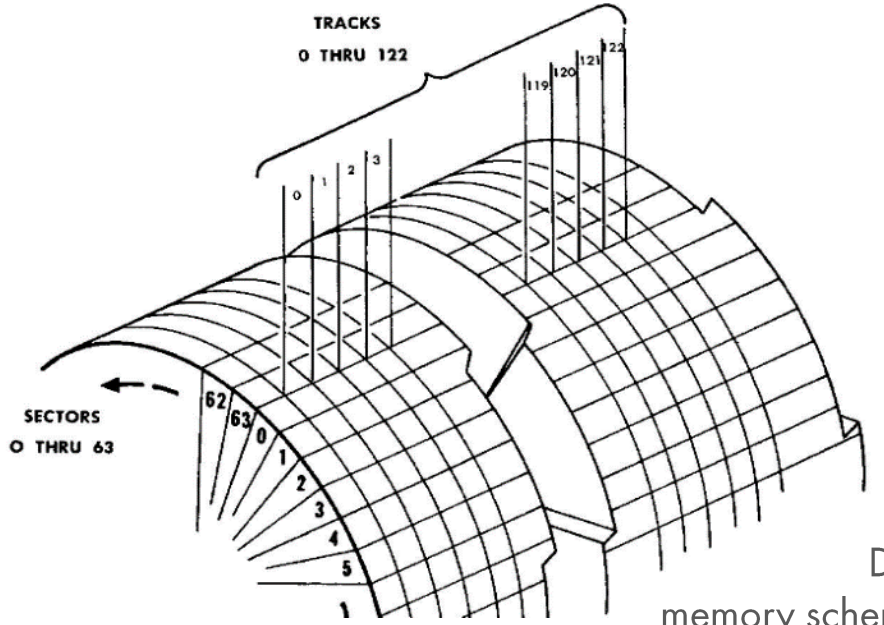
- Magnetic drum memory
  - Mainstream in the 1950s
  - Librascope and Royal Precision – success with small computers
- The RPC-4000 – and why it failed
  - Getting performance out of a magnetic drum
  - Market reception and competitors
  - The Story of Mel
- RPC-4000 replica project
  - Pocket-sized replica in an FPGA
  - The quest for software



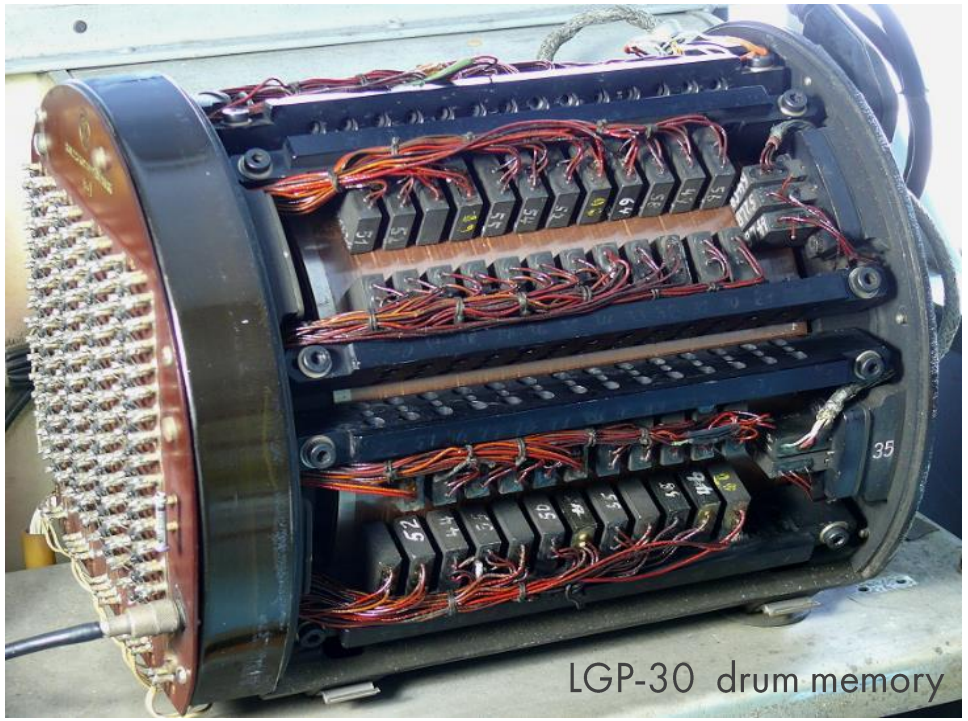
MAGNETIC DRUMS

MAGNETIC DRUM MEMORY

- Invented 1932 by Gustav Tauschek, Wien/New York/Zürich
- Cylinder with ferro-magnetic coating, one read/write head per track
- Precursor of the hard disk – but used as main memory!
- *Not* random access! Optimize program and data storage locations for fastest access on the drum.
- Access times: milliseconds
- Capacity: several 1000 words



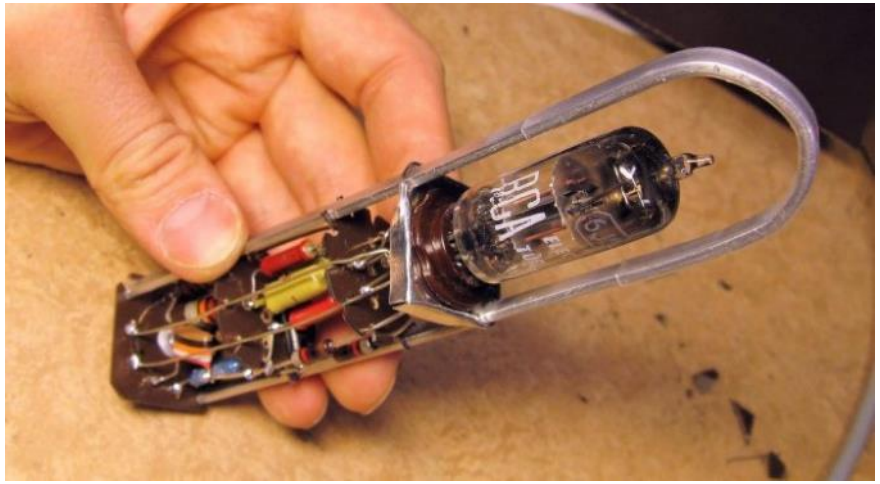
Drum memory schematic


LGP-30 drum memory

MEMORY ALTERNATIVES

Tube flip-flops – early 1940s

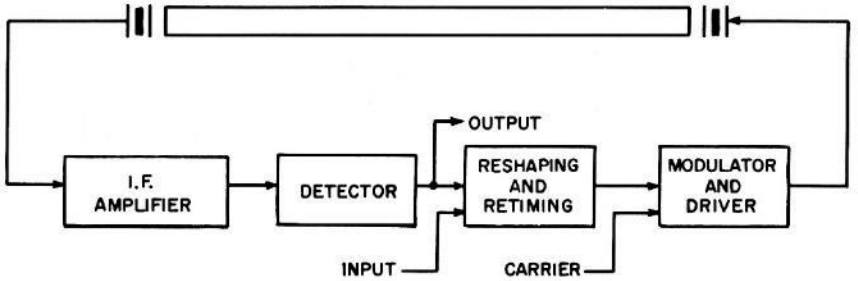
- Fast, random access
- One tube (dual triode) per bit, plus addressing logic.
- Expensive!
- Unreliable – too many tubes which can fail

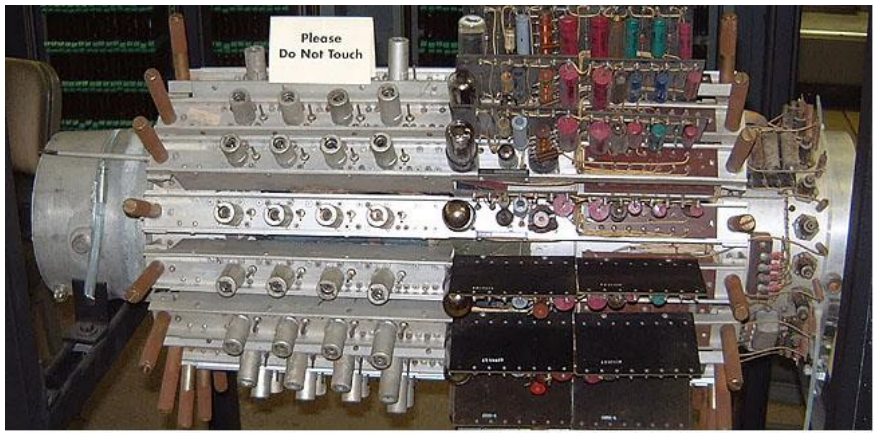


One bit
from the
IBM Model 604

Mercury delay lines – mid 1940s

- Expensive and finicky
- Faster, but still sequential.
  Access times few100 microseconds
- Limited capacity:
  100 .. 1000 bits per delay line



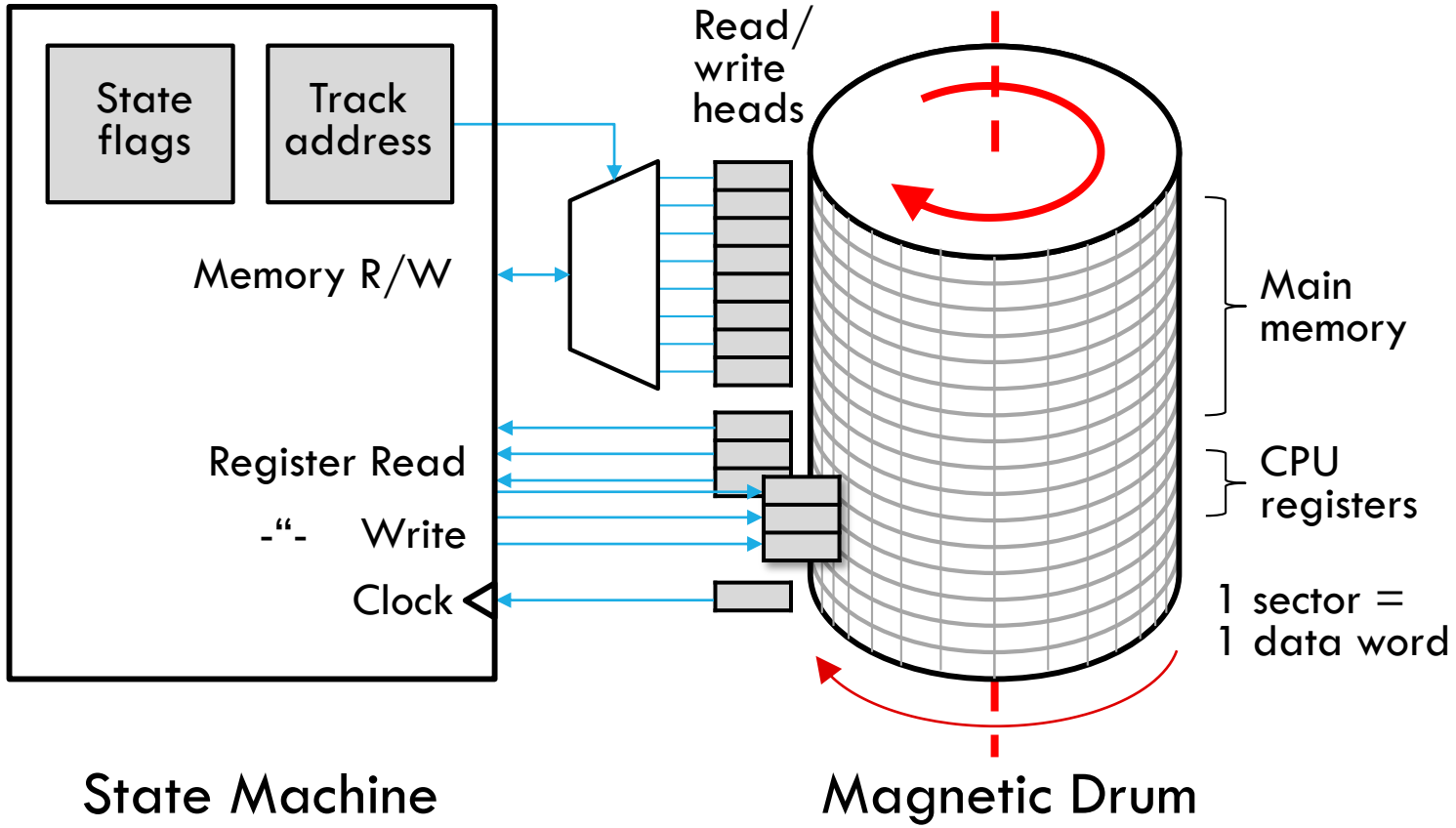


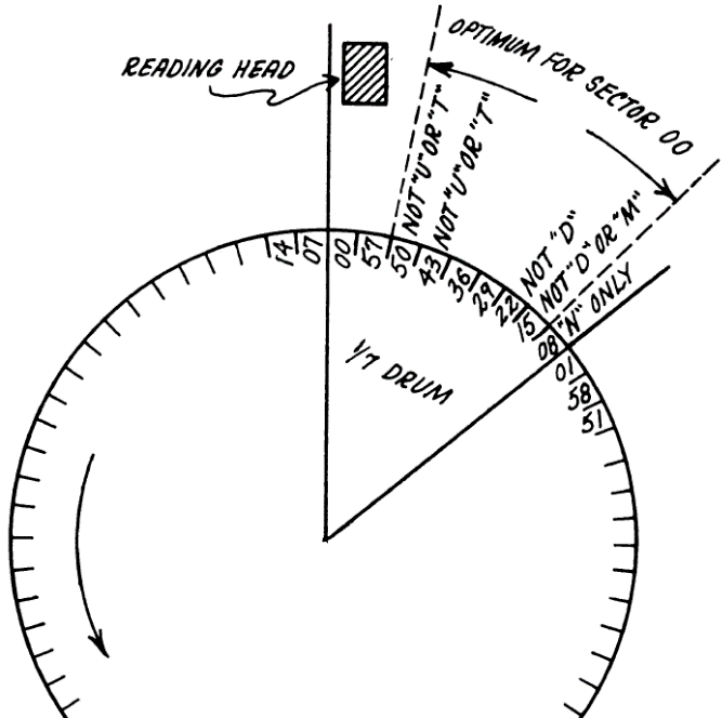
Delay line
block diagram
and UNIVAC
implementation

COMPUTER ARCHITECTURE

Bit-serial design –
all logic handles one bit at a time.

Main memory is not "random access".
Place data and instructions thoughtfully to get good performance!





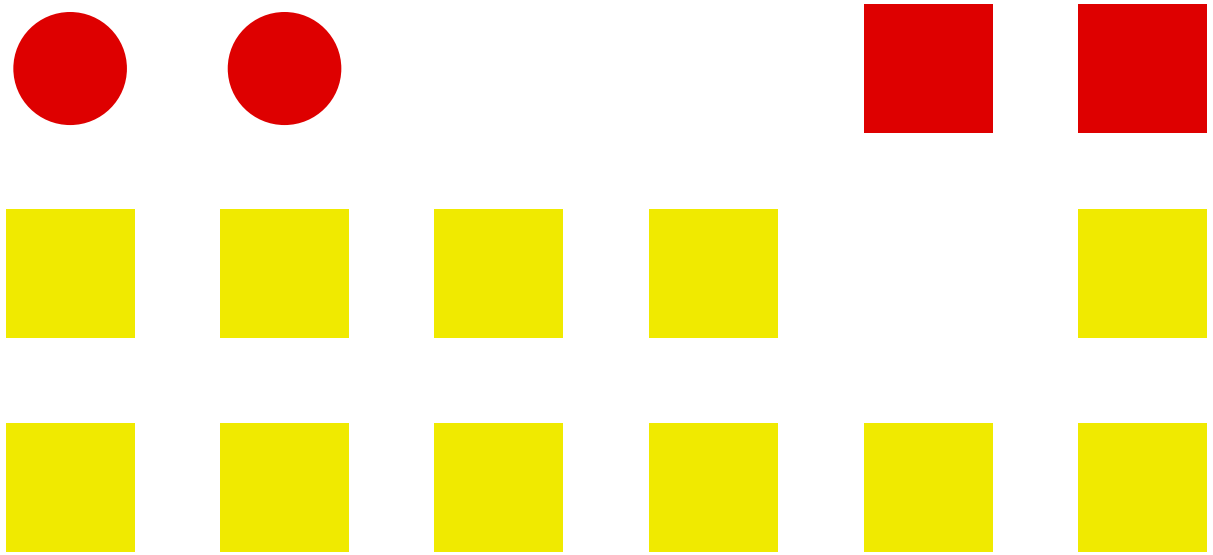
Address interleaving optimizes data and instruction access

DRUM MEMORY COMPUTERS

- Small to mid-range commercial computers,
  produced in "large" quantities, first appeared in the mid 1950s
- Most of them were based on magnetic drum memory at that time.

Manufacturer	Model	First sold	Price (1961)	Units (1961)	Drum Memory Capacity	Number of Tubes	Add Time (1 Word)
IBM	650	1954	$180,000	2000?	1..4k * 10 dig	~1300	290 µs
Librascope	LGP-30	1955	$49,500	460	4k * 31 bit	113	520 µs
Bendix	G-15	1956	$51,000	300	2k * 29 bit	450	540 µs
Borroughs	B205	1956	$150,000	112	4k * 10 dig	~1200	~1100 µs

Data from 1961 BRL Report, www.ed-thelen.org/comp-hist/BRL61.html

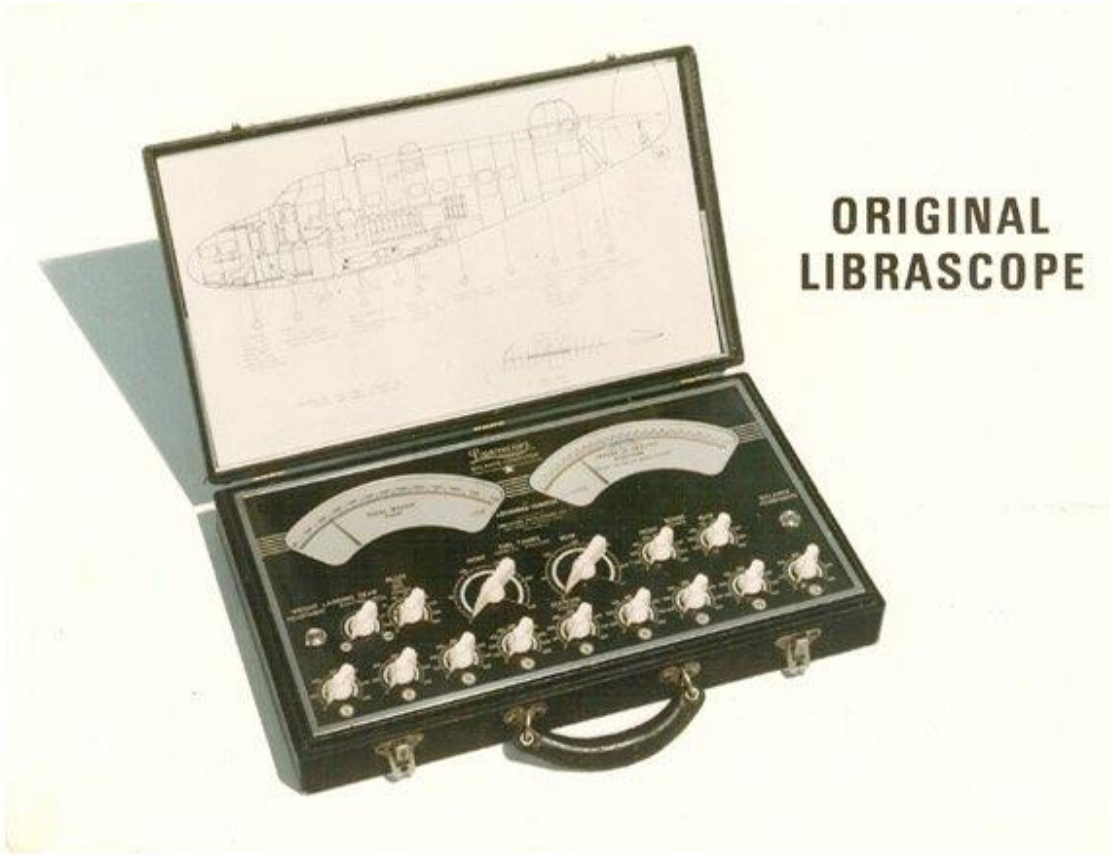


LIBRASCOPE AND ROYAL PRECISION

LIBRASCOPE – 1937

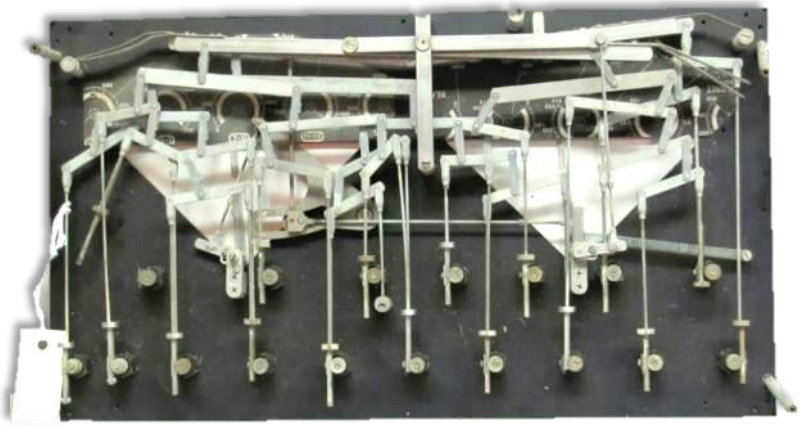
Librascope Development Company
Glendale, California

Founded by Lewis W. Imm,
Aeronautics engineer



The original „Librascope“:

An analog computer
for aircraft load balancing



LIBRASCOPE – 1955

Acquired by General Precision (1941)

Digital computers for defense

New partnership with Royal McBee, Computers for "general purpose" use

General Precision
Defense technology

Librascope
Digital computers

R&D
Manufacturing

Royal McBee

New York
Office machines

Sales
Service

Royal Precision
Computers for engineering and office use

LIBRAZETTE

AN EXCHANGE OF NEWS AND KNOWLEDGE

Published By
LIBRASCOPE EMPLOYEES
GLENDALE, CALIFORNIA

Volume 3, No. 10 November, 1955

Librascope's Amazing New General Purpose Computer Put on Market

by JOE MESCH
Librazette News Editor

Librascope unveiled a strong entrant in the digital computer field when it took the wraps off the LGP-30 at the second annual Automation Show and Computer Clinic in Chicago.

The LGP-30 is a low-cost, compact and easy-to-operate general purpose digital computer that possesses the memory capacity and problem solving ability of electronic brains costing ten times as much.

As such, it will be of special value to universities, technical consulting agencies, engineering firms (such as Librascope) and similar groups having problems requiring the services of a general purpose digital computer but lacking the funds heretofore required for its purchase.

In addition, the LGP-30 could be a valuable adjunct to organizations used to solve problems which would not warrant use of such computers as UNIVAC or a 702, but which are too complex and time consuming for manual computation.

Librascope's newest commercial product has been under company development since mid-1954. A California Institute of Technology scientist, Dr. Stanley Frankel, is responsible for the basic design of the LGP-30. Librascope, seeking new entries for its commercial stable, evaluated his design together with several others early last year and chose Dr. Frankel's as the most promising.

The core of the LGP-30 design is its memory unit—a magnetic drum capable of storing 4096 words, 32 bits (binary digits) in length, along 64 tracks around the drum's circumference.

Rotating at a speed of 3600 rpm, the drum is scanned, or read, by 64 read-record heads permitting access to any given word in a maximum time of 18 milliseconds. In operation, an access time of 2 milliseconds is more typical.

Thus, suitably programmed, the LGP-30 can add, subtract, multiply, and divide the contents of its memory unit approximately 1000 times as fast as can the ordinary desk calculator. In speed of operation, it stands midway between a desk calculator and high-speed computers of the UNIVAC type.

(Continued on page 3)

THE LGP-30 – 1955

A tube-age personal computer

- Programmed and run by a single user
- Sits right by your desk – mobile, on wheels
- Focus on science, engineering, finance

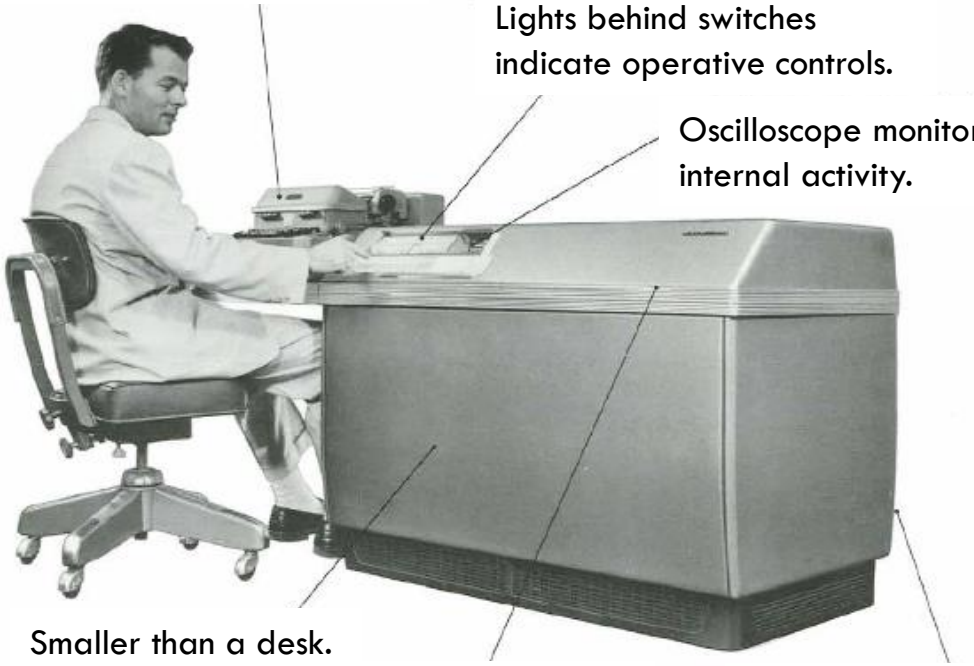
Amazingly simple

- Design by Stan Frankel, Caltech
- 113 tubes total – only 24 for the CPU!
- Bit-serial design – a state machine driven by the magnetic drum
- 31 bit architecture, 4096 word memory
- 16 instructions, including hardware multiplication and division

An electric typewriter gives alpha-numeric entries or output by punched tape or keyboard.

Simplified control panel. Lights behind switches indicate operative controls.

Oscilloscope monitors internal activity.



Smaller than a desk.

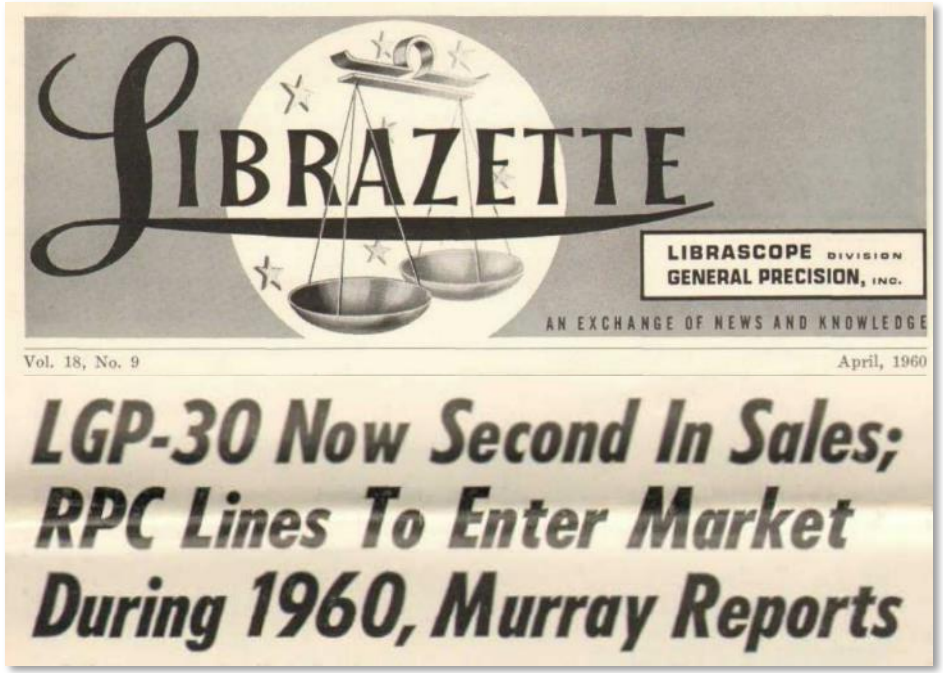
4096 word magnetic drum memory.

Computer operates from any convenience outlet … is self-cooled.

LIBRASCOPE – 1960

- Market leader in small computers!
- 350 LGP-30s shipped until end of 1959, and another 100 during 1960
- Only IBM has a better seller – IBM 650, a larger system, 2000 sold

Where to go next?
Upmarket, head-to-head with IBM!



LIBRAZETTE

LIBRASCOPE DIVISION GENERAL PRECISION, INC.

AN EXCHANGE OF NEWS AND KNOWLEDGE

Vol. 18, No. 9 April, 1960

LGP-30 Now Second In Sales; RPC Lines To Enter Market During 1960, Murray Reports

In an annual report to GPE shareholders, Murray said, "One of the computers, the LGP-30, is now second in numbers sold among all computers on the market. By the end of last year, 350 units had been shipped.

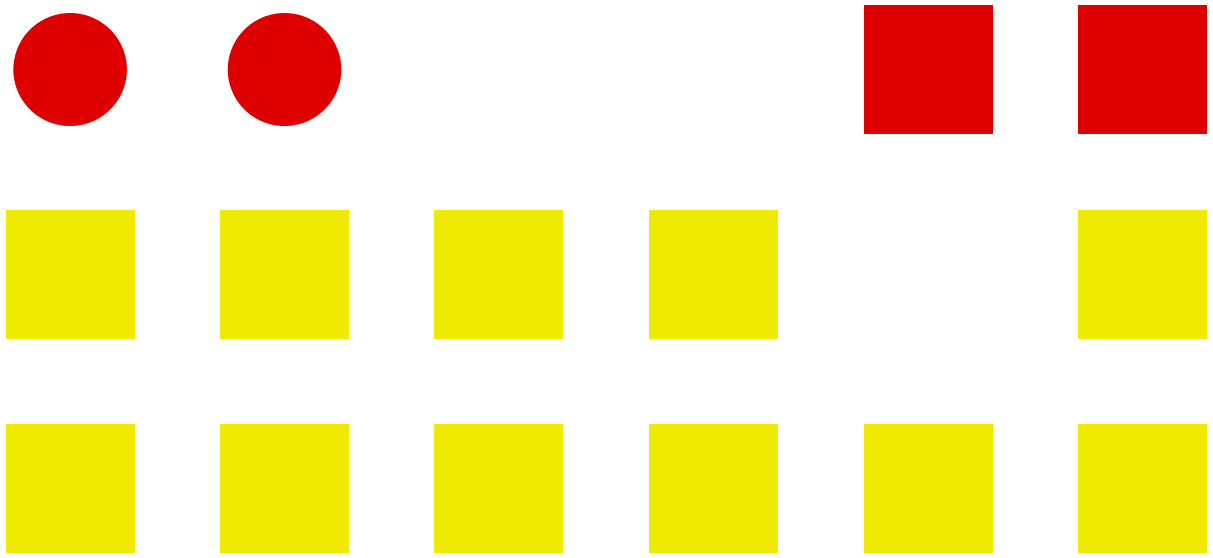
Scheduled for production and sales later this year is a second line of desk-size computers, the *RPC 4000*.

"**THIS COMPUTER** is fully transistorized," Murray said. "And it has the largest memory capacity of any computer its size—more than 8,000 words."

RPC-4000

Shipping early 1961

Fully transistorized
Enhanced instruction set
Flexible peripheral architecture
... and a slow, non-random-access magnetic drum!



THE RPC-4000 AND ITS COMPETITORS

SPECIFICATIONS

Functionality

- 32 bit words
- 8000 words main memory
- Fixed-point multiply & divide in hardware; floating point libraries
- Two accumulators, one switchable to 8 words
- Index register for arrays and repeats
- 32 instructions
- Bit-serial architecture

Speed

- Drum speed 3600 rpm
- Bit clock 120 kHz
- Memory access time:
  8.5 ms average, 17 ms maximum
- Fast track access time:
  1 ms average, 2 ms maximum
- Addition, Subtraction time: 1 ms
  (with optimized data access)
- Addition, Subtraction repeats: 0.25ms
- Memory search: 3000 words/s

PERFORMANCE FROM A SPINNING DRUM

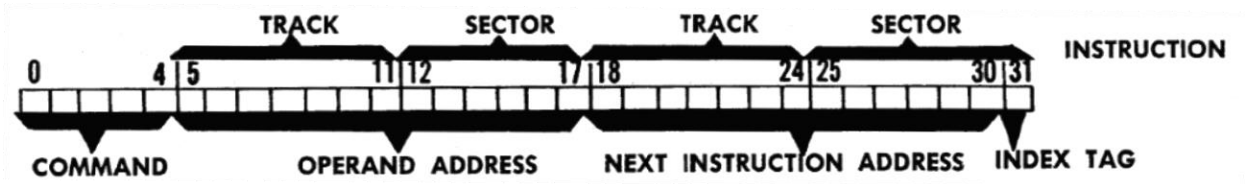
More flexibility to place instructions and data at optimum addresses

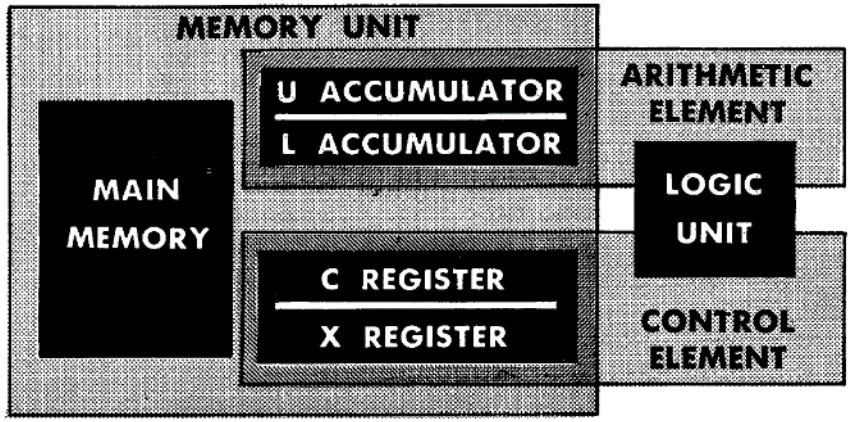
"One over one" addressing –
each instruction has two address fields

- Operand address
- Next instruction address (implicit "goto"!)

Known from IBM 650, Bendix G15, Turing's Pilot ACE

This CPU has no program counter!
Takes some getting used to...

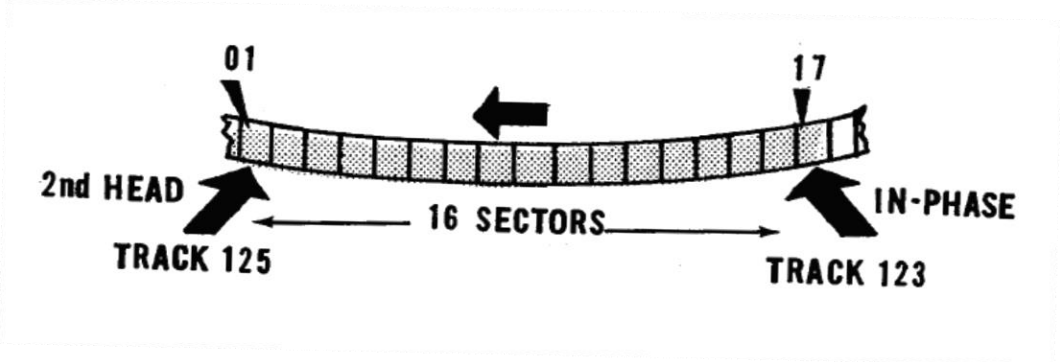


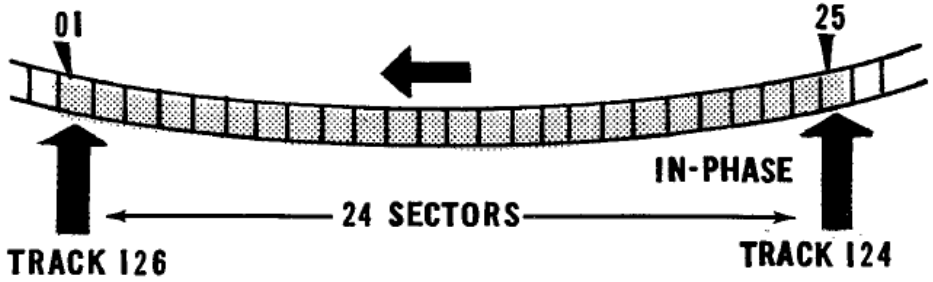


FAST TRACKS

Read – modify – write is a common pattern.

- Problem: Can optimize data location for fast reading, but have to wait a full revolution to write data back
- Solution: Dual access tracks!
- Two special data tracks, each with two read/write heads. Can get to the same word again 16 or 24 cycles later.

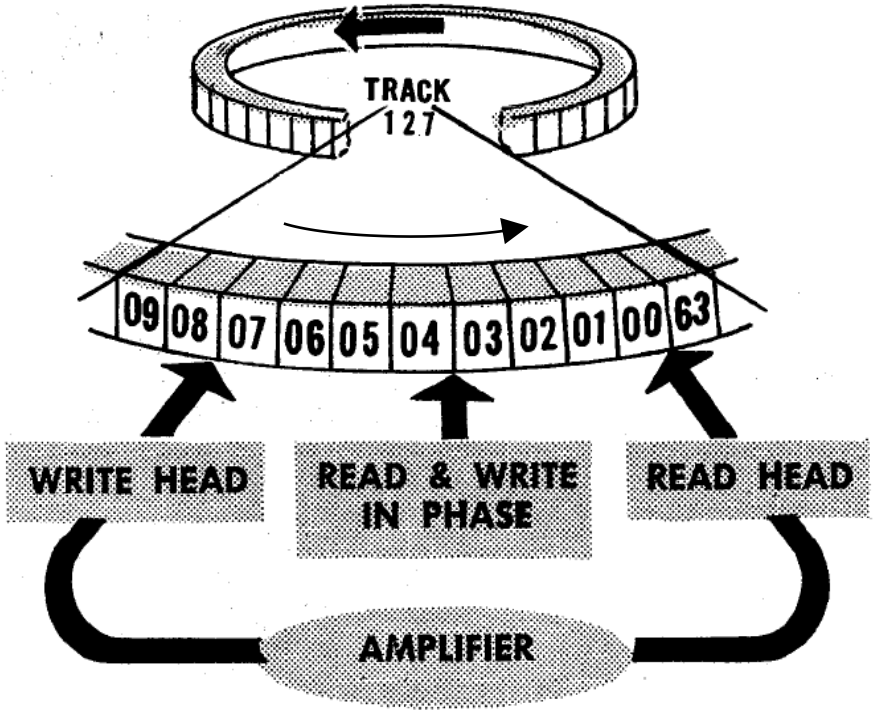




EVEN FASTER TRACK!

Some data need to be accessed often, from different program locations

- Recirculating track stores 8 words, which automatically repeat 8 times around the full track
- Dedicated write head always copies what is seen by a read head 8 words downstream
- Worst-case access time 8 words (2 ms)



BLOCK MATH AND SEARCH!

Indexed addressing mode

- 7 bit index register added to operand address
- Use for simple array indexing
- … but lose control of optimum data placement – consecutive addresses only!

Repeat instruction

- Repeat a single instruction up to 128 times
- Acts on consecutive memory words on the drum – only 0.25 ms per word!
- Works for e.g. ADD, SUB, STORE
- Use with 8-word accumulator for 8-word block arithmetic

Block search

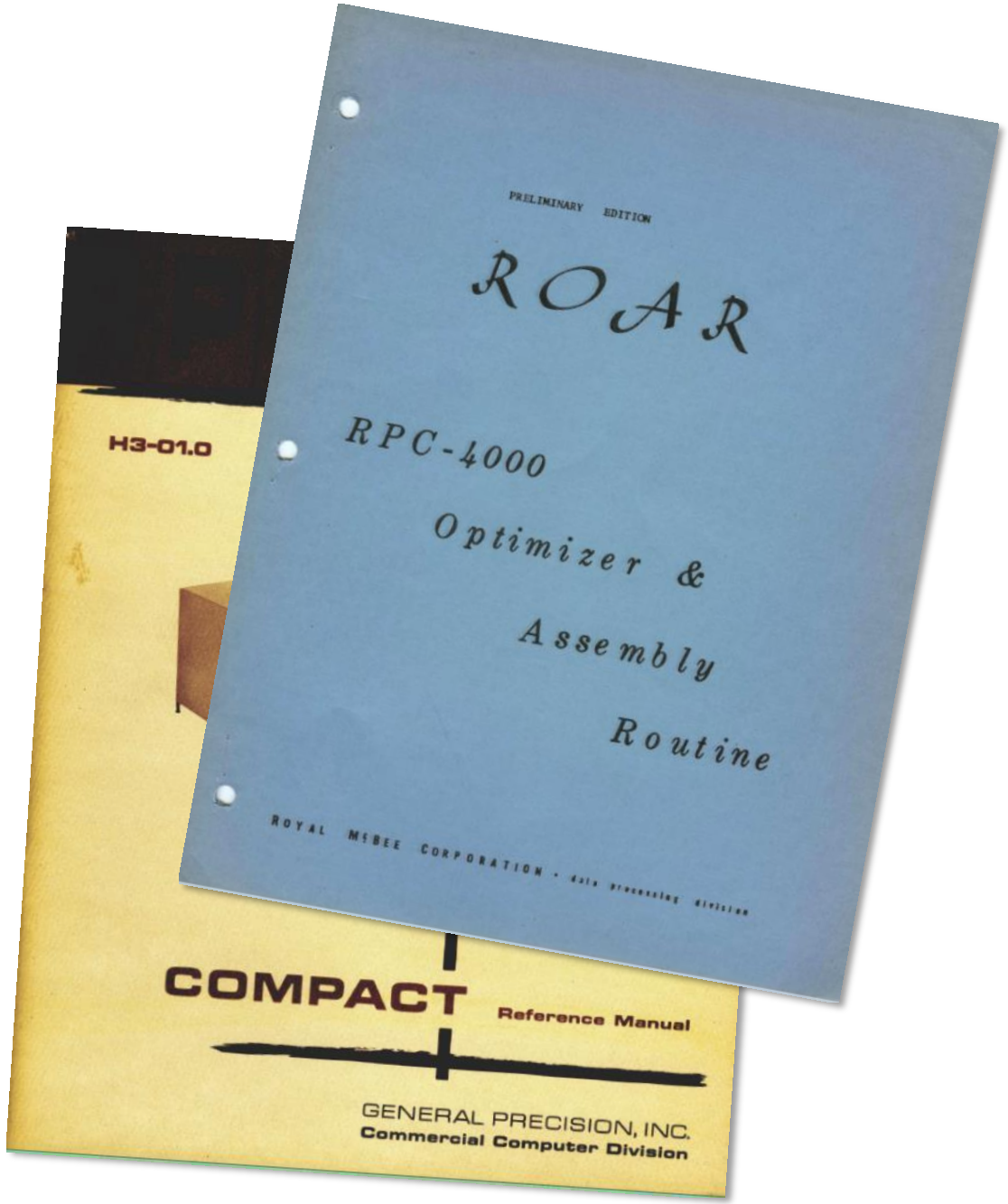
- Use Compare in repeat mode (CME, CMG)
- Specified at 3000 words/s, executes at 4000 words/s once set up

MANAGING COMPLEXITY – THE ROAR ASSEMBLER

INTRODUCTION

The object of an assembly program is to allow the programmer to code instruction for instruction like actual machine language, but to be relieved of the extra chores of optimizing, keeping track of used locations, etc.

With the "one over one" addressing system of the RPC-4000, optimization is doubly necessary. It was with these considerations in mind that the first major program for the RPC-4000 should be a symbolic assembler and optimizer.



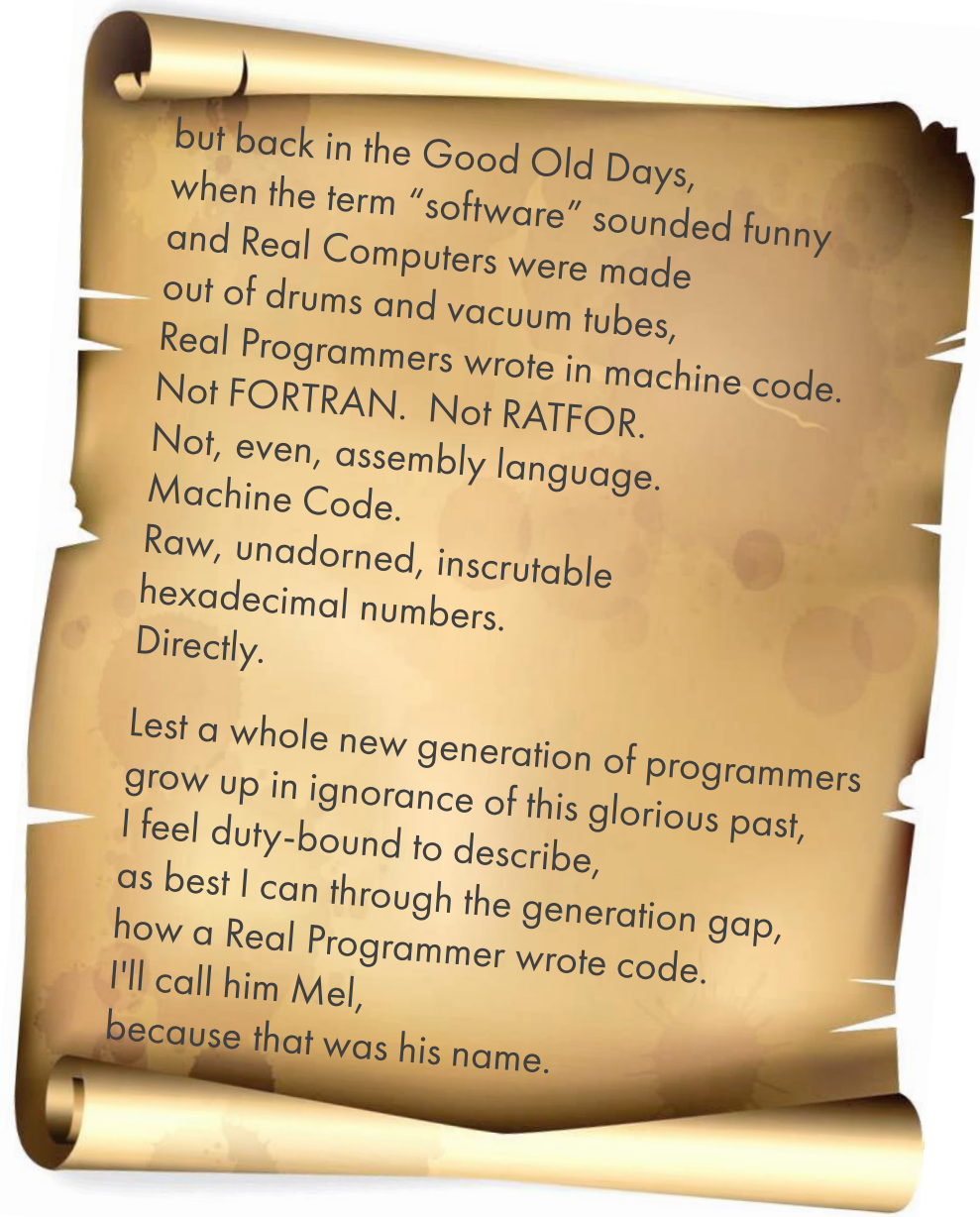
THE STORY OF MEL

"Real programmers" did not use those new-fangled tools! ☺

A favorite piece of hacker folklore, told by Ed Nather on Usenet in 1983, preserved in the Jargon File.

Starring

- Mel Kaye, programmer at Librascope,
- and the RPC-4000!

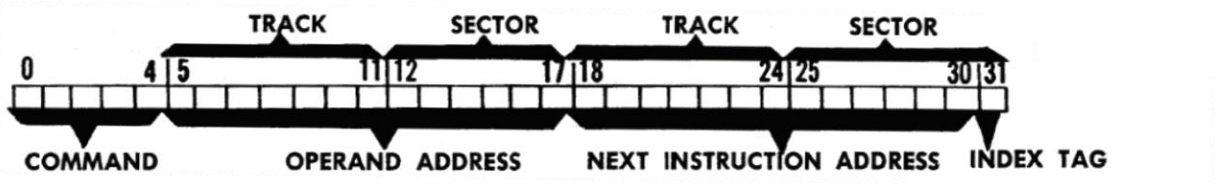


Ed Nather, May 1983
www.catb.org/jargon/html/story-of-mel.html

MEL WAS FOR REAL

... but technically, the story is not accurate:

- Yes, you could let the Operand Address overflow into the Command field, to terminate an infinite loop;
- but the Index bit has nothing to do with that.
- Also, executing an instruction directly from a CPU register is not supported.



BLACKJACK GAME
(By Mel Kaye of Librascope Inc.)

RPC-4000
Program W1-01.0

This program is designed to simulate a game of Blackjack between one player (the machine operator) and a dealer (the computer). This write-up is intended to provide the player with the information necessary to play the game.

Before playing Blackjack, set
4 columns of
(left

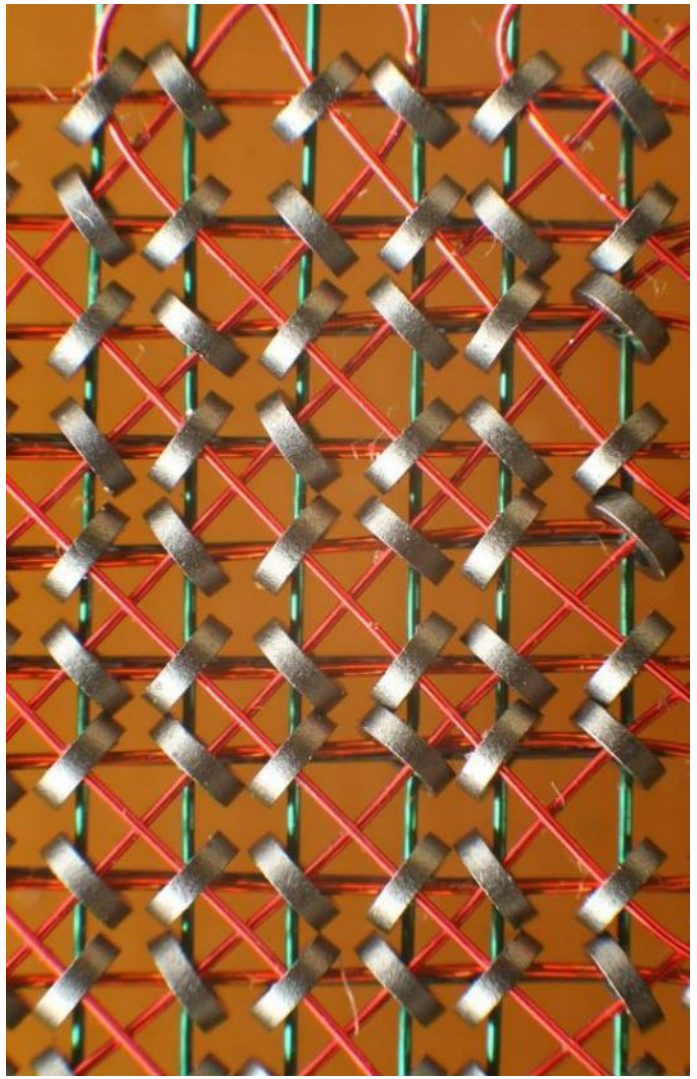
LIBRASCOPE'S MURAL ROOM became a study hall for neophyte LPG-30 programmers the week of July 16. Students participating in this first training school for LPG-30 customers included (seated l. to r.) Bill Hopper, Mary Cornell and Chuck Rue, Convair-Pomona; John Corkhill, Convair-San Diego; R. J. Bibbins, Link Aviation; K. A. Hurst, D. D. Parkhurst, C. S. Kikushima and Ides J. Romero, Convair-San Diego; George Kendrick, Convair-Pomona; Chuck Ray, Caltech; and William Clayton, National Security Agency. Standing (l. to r.) are Fred Flannell, class instructor and assistant sales manager of Royal-McBee; and Royal-McBee Applications Engineers Bud Hazlett, Jack Behr and Mel Kaye. (Photo by Duggan)

Librazette, August 1956

MARKET RECEPTION

"Too slow, too late..."
Ferrite-core memory had reached the scene!

	RPC-4000	IBM 1401	DEC PDP-1
Launched	1960	1959	1960
Memory Type	Drum	Core	Core
Memory Size	8k * 32 bit	1k .. 16k char	4k * 18 bit
Clock Rate	120 kHz/bit	87 kHz/char	187 kHz/word
Additions/s	1 000	3 000	93 000
Units Sold	104 (4 years)	2600 (2 years)	53 (total)

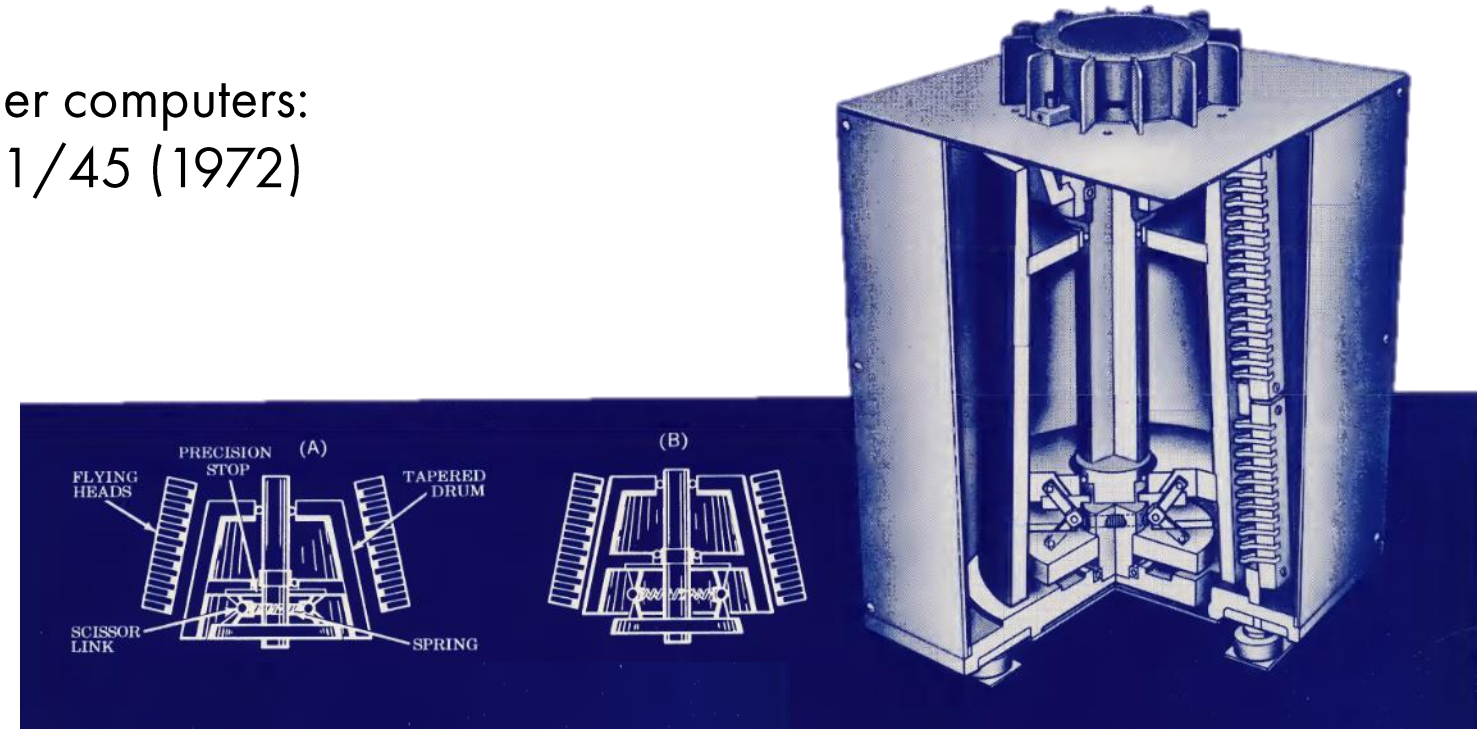


Core memory. Photo by Konstantin Lanzet

WHAT BECAME OF MAGNETIC DRUMS?

- Used as main memory in low-end computers:
  e.g. Robotron SER2 (1962), Cellatron C8205 (1969),
  Litton ABS 1230 (~1970)
- Used for page swapping in larger computers:
  e.g. Ferranti Atlas (1962), PDP11/45 (1972)
- Continued development:
  Floating heads,
  higher bit density,
  faster drum rotation
- Eventually magnetic disks
  take over (1970s)

Bryant Auto-Lift ™ drum and
"aerodynamic heads", 1965

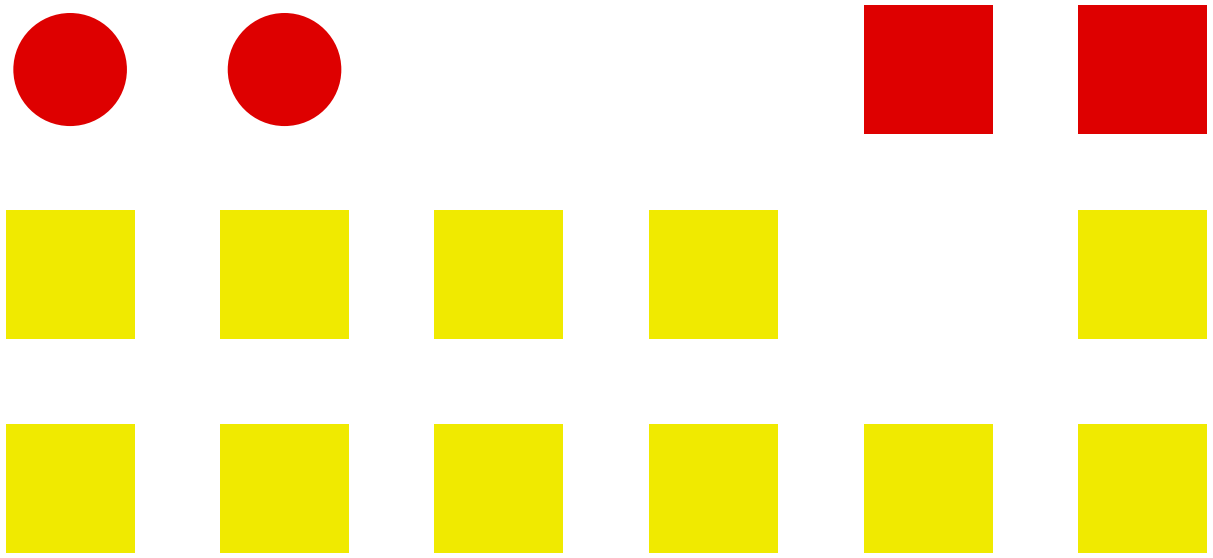


WHAT BECAME OF LIBRASCOPE?

1965	Computer business sold to Control Data; Librascope refocuses on military technology.
1968	sold to Singer (of sewing machine fame)
1991	sold to Loral Corp.
1996	sold to Lockheed Martin
2000	Glendale site closed

http://www.librascopememories.com
Site by former employees, with recollections and documents (including Librazette from 1940 to 1999)

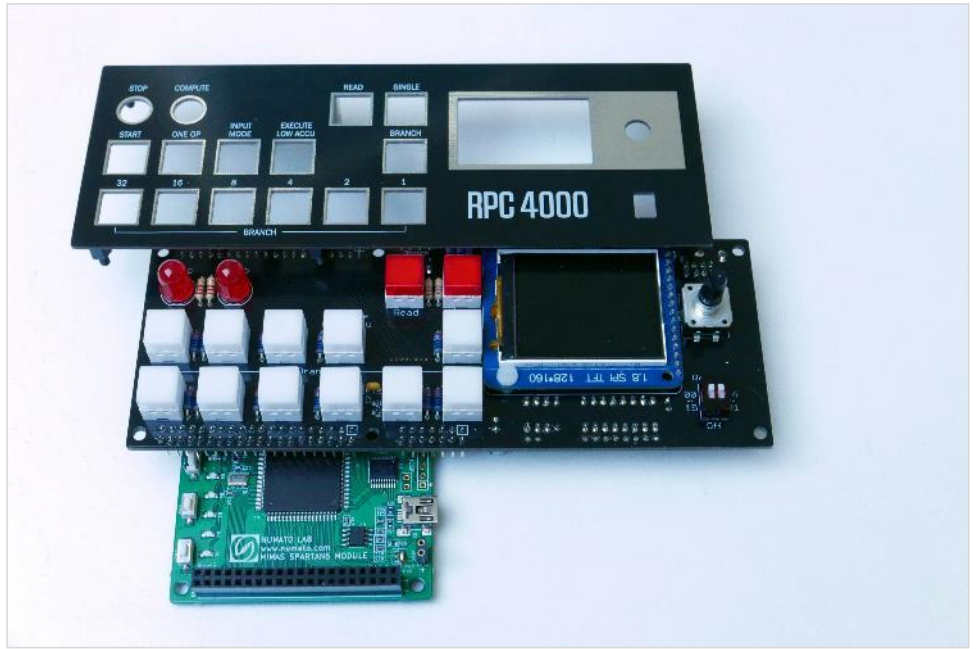
The only surviving RPC-4000?
Computer History Museum, Mountain View CA
computerhistory.org/collections/catalog/X786.86



RPC-4000 REPLICA PROJECT

MAKING IT WORK

- All logic in a low-cost FPGA –
  Xilinx Spartan 6, Numato Mimas board
- Front panel circuit board for user interface –
  switches, “oscilloscope” display,
  peripheral connectors
- Front panel overlay for cosmetics –
  also a PCB, low cost, complete with cutouts
- Connect an external computer for
  terminal and paper tape simulation –
  USB interface, also provides power



MAKING IT VISIBLE

- Oscilloscope shows registers in original RPC-4000.

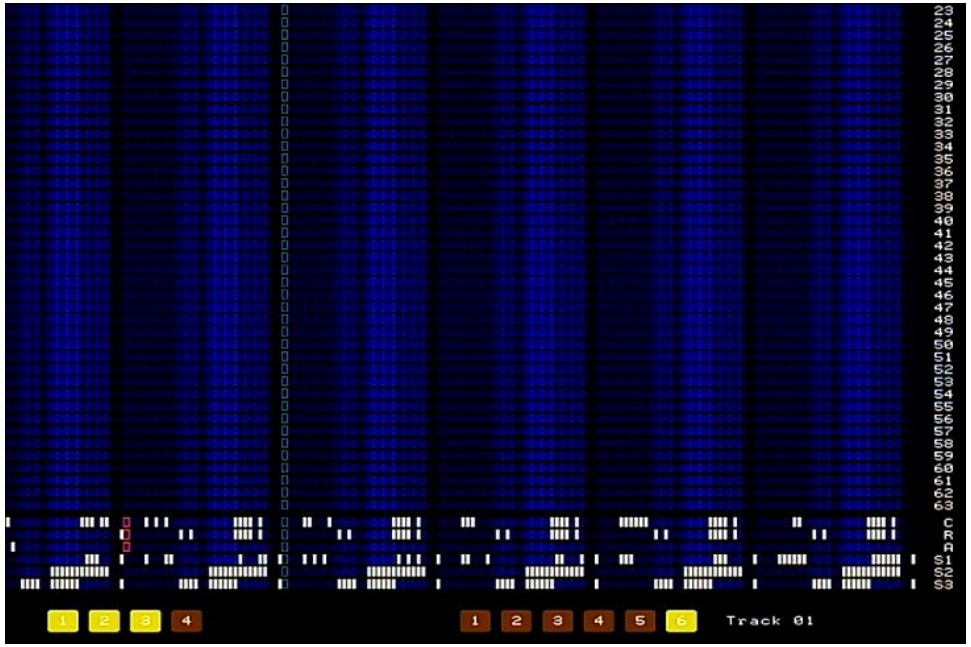
  Color TFT displays oscilloscope, screen overlay, and replica status in the top line.

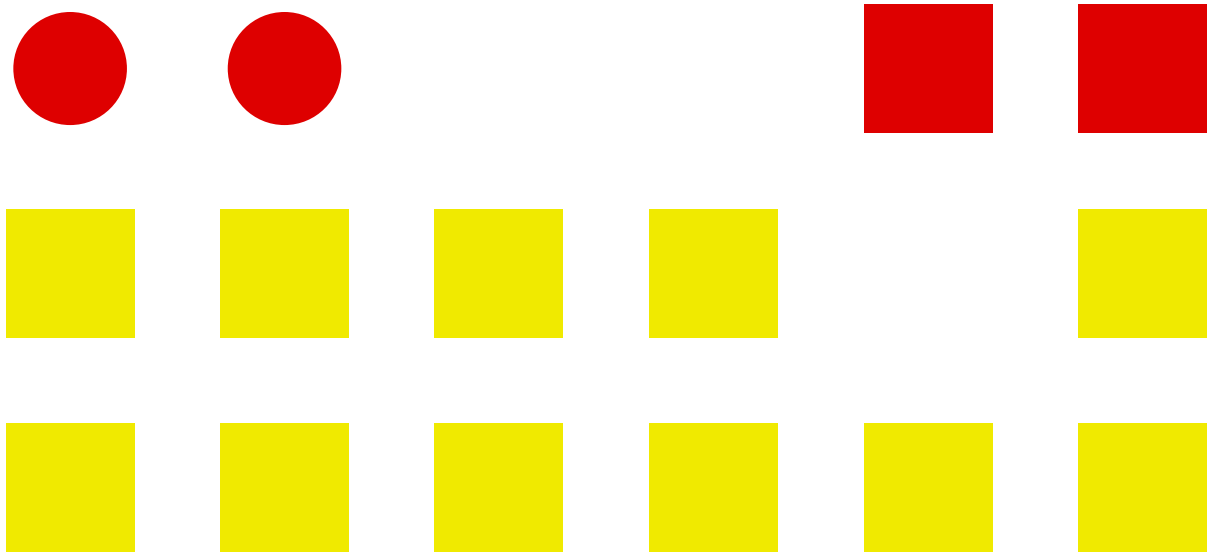
- Rotary switch in original RPC-4000 selects Lower Accumulator display.

  In the replica, also controls clock speed and display scrolling.

- Magnetic drum resides in FPGA memory.

  Made “tangible” via HDMI display. “Spins” in real time when the replica clock is slowed down.





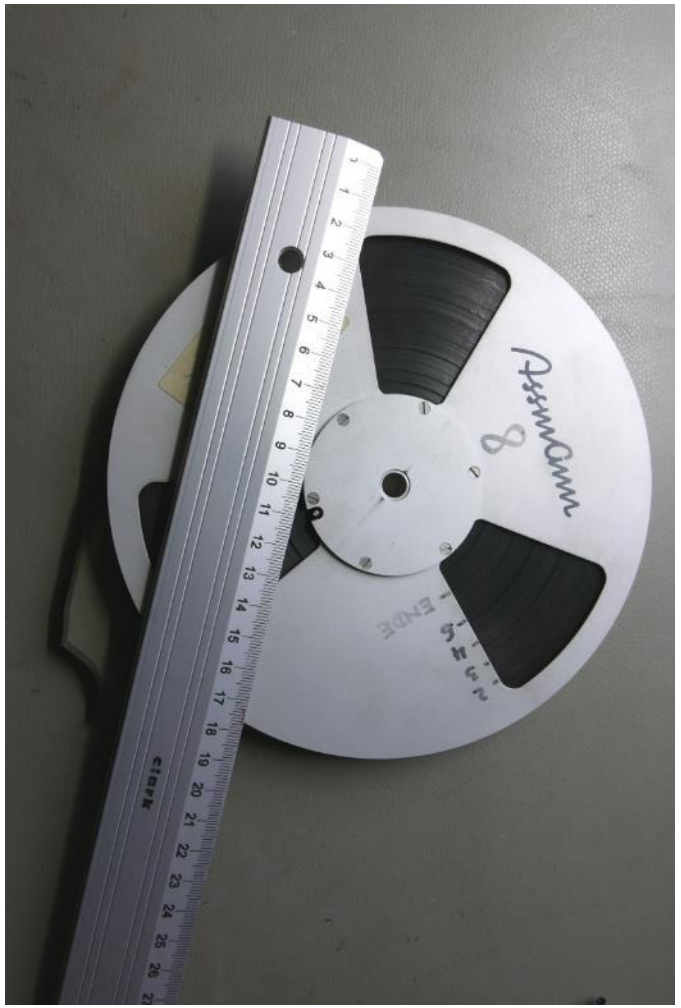
THE QUEST FOR SOFTWARE

WHERE'S THE SOFTWARE?

There is NO software available online at all.
(Yes, I knew when I started the replica build...)

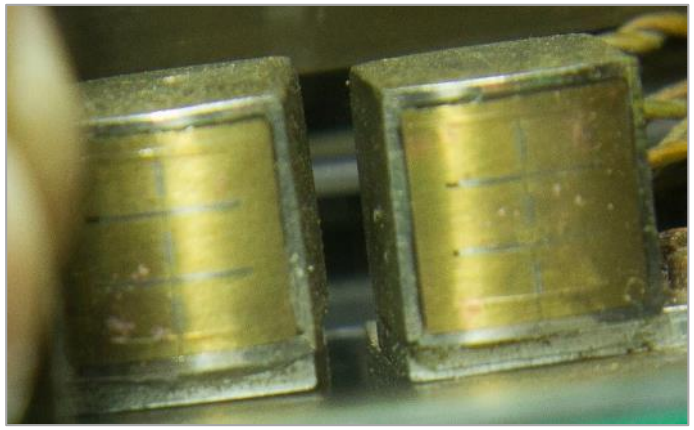
Two leads to software:

- Control Data Corp. paper tapes, in Paul Pierce's collection.
  Tapes are damaged and not accessible. ☹
- Munich University's astronomic observatory:
  Once had an RPC-4000, with a rare magnetic tape drive.
  A few tapes were preserved!
  And I got a "System" tape on loan! ☺☺



READING A TAPE?

- Tape unit made by Schoppe & Faeser, Germany. Actual tape drive made by Assmann.
- Some documentation is still preserved – including basic format information. ☺
- An actual tape unit is still preserved! ☺☺ Technikum29, Kelkheim, part of their LGP-21.
- Tape control is tightly meshed with LGP-21, both are non-working. ☹
- Actual 3-track read/write heads are used. How to read *that* tape? ☹☹



Assmann 3-track heads

Schoppe & Faeser tape drive on LGP-21

READING A TAPE!

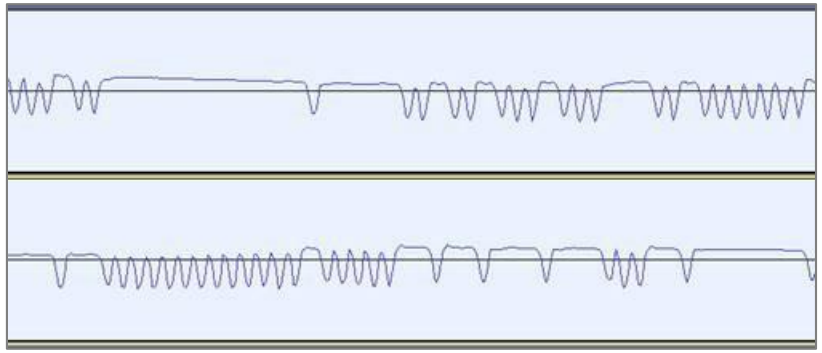
- Tape amateurs to the rescue!
- Fostex R8 home studio 8-track
  can mount the spool
  and read the odd tracks
- Digitize complete tape into WAV
- …

READING A TAPE!

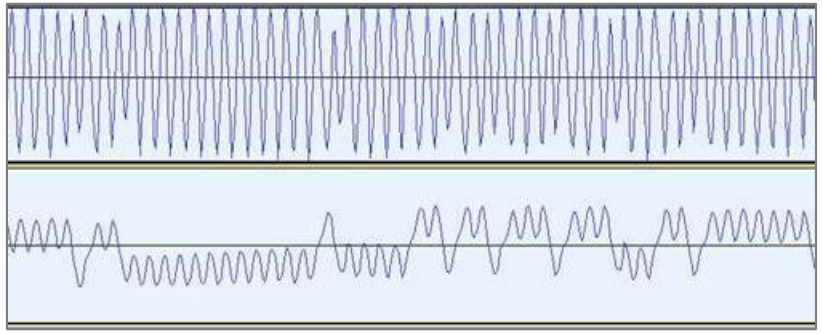
- …
- Digitize complete tape into WAV
- Split data blocks, filter and demodulate via Python script
- Modulation format as expected
- Sorry ☹☹ –
  that's not valid RPC-4000 code…

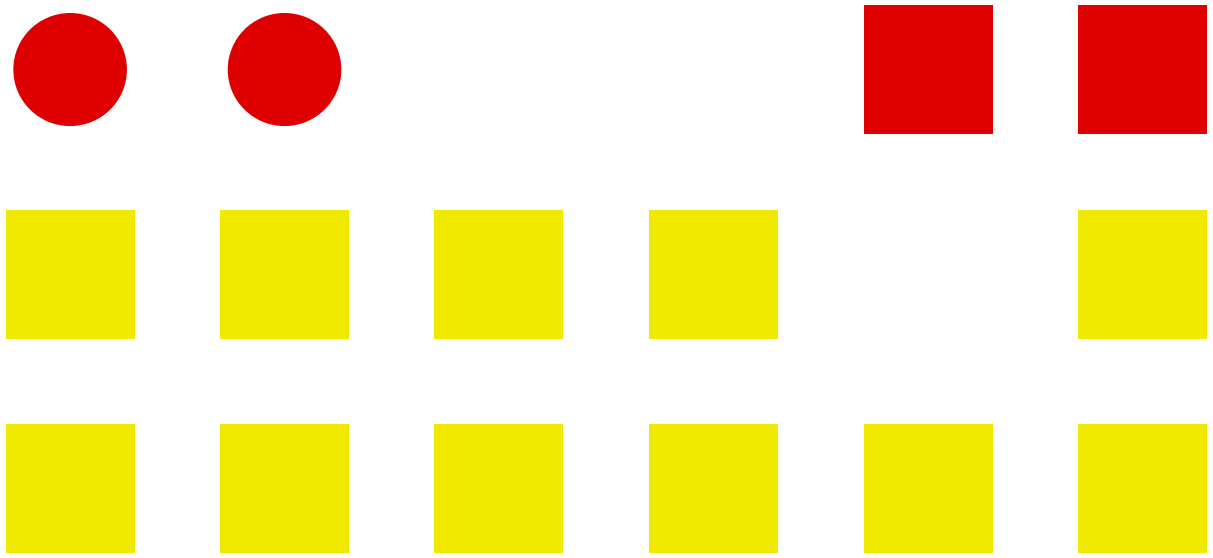
Data track and block marker track

Raw data tracks, normal and inverted



Difference and sum of tracks give clock and data





THANK YOU

for listening
for questions
for leads to software!

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