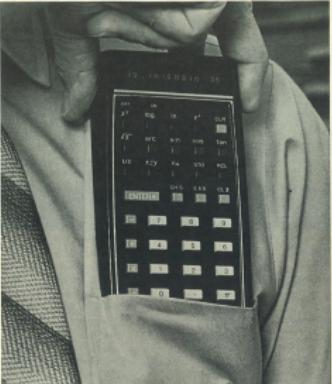




- ▶ This is a **HP-35 calculator**
  - ▶ Released in 1972, priced \$395, i.e., about the same as a modern laptop!
  - ▶ Discontinued in 1975 or so (due to newer models such as HP-45).
- ▶ which is essentially a simple *computer*.
- ▶ **Question:** can we develop a (limited) HP-35 implementation using content from COMS12200 thus far?
- ▶ **Answer:** yes.

## Some things are changing for the better.

Many people know us as an instrument manufacturer; we make more than 2,000 products for measurement, test and analysis. Others know us as a computer company; more than 10,000 own our desktop computers and workstations. Computers. We prefer to think that our business is to serve measurement, analysis and computing needs... and to help people learn and educate. That is the rationale behind every one instrument, computer or system that we sell you about in these ads. This exists:



The HP-35 SH/T Pocket Calculator lets you compute complex calculations like this one approximately five times faster than with your slide rule... with 10 place accuracy.

$$\text{N}_2 = \left( \frac{1}{2} \cdot \frac{10^5}{M} \right) \left( \frac{10^3}{T} \right)^{1.28} \left( \frac{P_{\text{atm}}}{10^3} \right)^{0.14}$$

$$\text{pH} = -\log \frac{1}{\left( \frac{10^5}{M} \right)^{0.5} \left( \frac{37.42}{T} \right)^{0.5}}$$

\*Chemists will recognize this as a calculation of the pH of a buffer solution for the review of No. 1100, HP-35 MSL and No. 1101, PC-35 ESR MSL.

### The new HP-35 Pocket Computer: a boon for scientists, engineers, or almost anyone.

When you first hear about it, it sounds like an electronic slide rule, the kind that's been available only in scientific fiction. Then again, you may be thinking, "It's a calculator, with rechargeable battery. It computes transcendental functions with a single keystroke, in less than a second. It calculates positive and negative numbers in floating point notation. It can even do square root! And it has a memory that keeps track of the decimal throughout its 200+ decimal places, and displays answers that are accurate to the 10th significant digit."

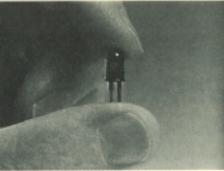
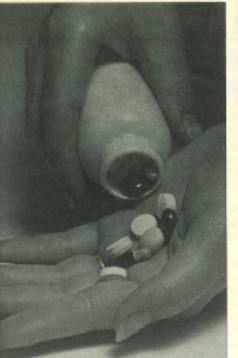
And when you use it, you soon realize that it is more like a computer than a super slide rule. The secret is its 4-register operational logic. Solidly based on computer theory, it holds intermediate answers in a higher register

and automatically brings them back when they are required for further calculations. The calculator also has a timer register that lets you set any time and recall it at the push of a button.

The power of our little wonder is illustrated in the calculation shown above. The HP-35 solves this problem in about two seconds and gives the answer to 10 significant digits. And it does it with a single keystroke, no less!

The new HP-35 Pocket Calculator contains the equivalent of 30,000 transistors in specially designed MOS/LSI circuits. Yet it costs just \$295 (domestic US price only). And it weighs only 12 oz., which is about as much as a great briefcase. But if your people need this kind of computation power, it's worth the weight. Just use the coupon and we'll send full information to you.

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 An HP Gas Chromatograph, used, good condition  
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## HP-35: A High-Level Overview (1)

- ▶ A HP-35 is internally comprised of three units, namely
  1. a 2-phase **clock generator**,
  2. a **Read Only Memory (ROM)** unit,
  3. an **Arithmetic and Register (A&R)** unit, and
  4. a **Control and Timing (C&T)** unit

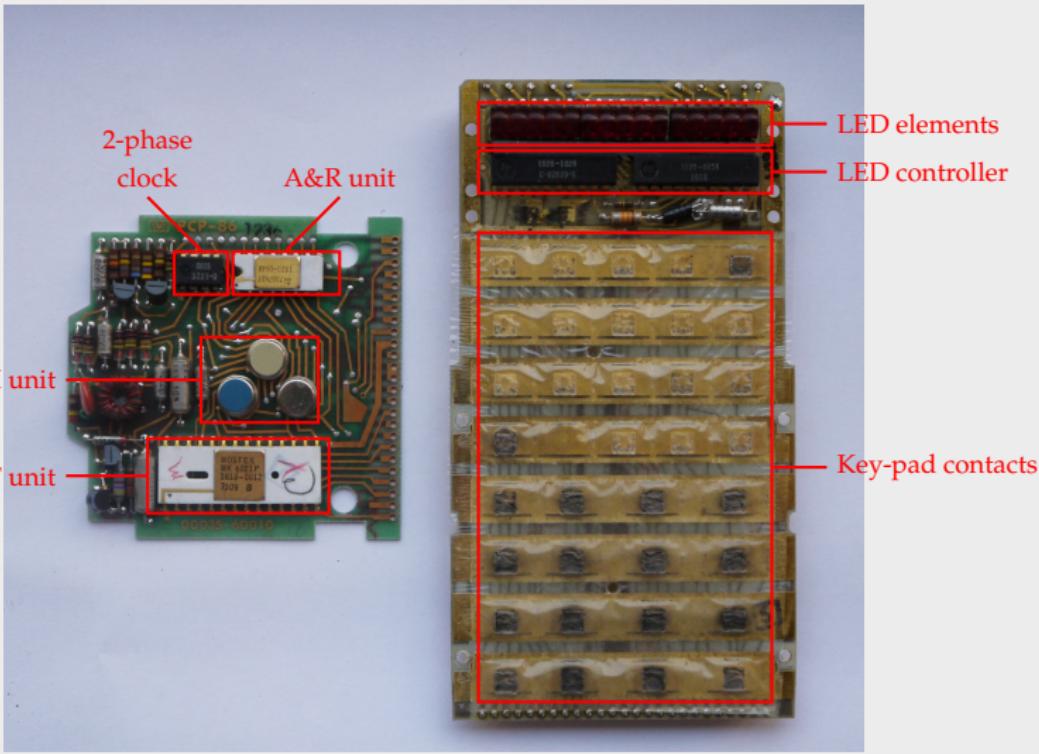
plus

1. a **keypad** to provide input, and
2. an **LED-based display** to provide output

and was used via **Reverse Polish Notation (RPN)**.

## HP-35: A High-Level Overview (2)

### Design



# HP-35: A High-Level Overview (3)

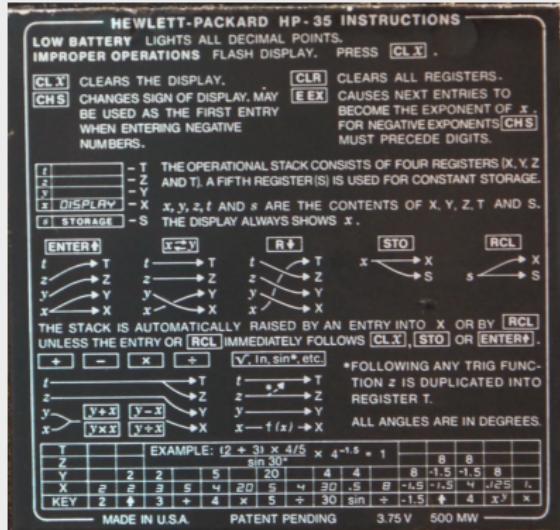
## Design



1. ' $V$ ' for  $V \in \{0, 1, \dots, 9\}$ 
  - ▶  $X' \leftarrow 10 \cdot X + V$
2. ' $\odot$ ' for  $\odot \in \{+, -, \times\}$ 
  - ▶  $X' \leftarrow Y \odot X, Y' \leftarrow Z, Z' \leftarrow T, T' \leftarrow T$
3. 'CLR' (or "clear")
  - ▶  $X' \leftarrow 0, Y' \leftarrow 0, Z' \leftarrow 0, T' \leftarrow 0$
4. 'STO' (or "store")
  - ▶  $S' \leftarrow X$
5. 'RCL' (or "recall")
  - ▶  $X' \leftarrow S$
6. '↑' (or "enter")
  - ▶  $X' \leftarrow X, Y' \leftarrow X, Z' \leftarrow Y, T' \leftarrow Z$

# HP-35: A High-Level Overview (3)

## Design



1. 'V' for  $V \in \{0, 1, \dots, 9\}$

►  $X' \leftarrow 10 \cdot X + V$

2. '⊖' for  $\ominus \in \{+, -, \times\}$

►  $X' \leftarrow Y \ominus X, Y' \leftarrow Z, Z' \leftarrow T, T' \leftarrow T$

3. 'CLR' (or "clear")

►  $X' \leftarrow 0, Y' \leftarrow 0, Z' \leftarrow 0, T' \leftarrow 0$

4. 'STO' (or "store")

►  $S' \leftarrow X$

5. 'RCL' (or "recall")

►  $X' \leftarrow S$

6. '↑' (or "enter")

►  $X' \leftarrow X, Y' \leftarrow X, Z' \leftarrow Y, T' \leftarrow Z$

## HP-35: A High-Level Overview (4)

- ▶ RPN is a notation for expressions: using

- ▶ **in-fix** operators give

$$(19 - 5) \times (1 + 2)$$

- ▶ **pre-fix** operators (or “Polish notation”) give

$$\times \ - \ 19 \ 5 \ + \ 1 \ 2,$$

and finally

- ▶ **post-fix** operators (or “reverse Polish notation”) give

$$19 \ 5 \ - \ 1 \ 2 \ + \ \times.$$

- ▶ **Advantages:** RPN is attractive because it

1. is unambiguous *without* parentheses, and
2. can be evaluated naturally using a **stack**.

## HP-35: A High-Level Overview (5)

- The HP-35 uses a slight variation; reconsider the RPN expression

19 5 – 1 2 + ×

evaluated using the following key presses

		Key-press										
		1	9	↑	5	–	1	↑	2	+	×	
Register	X	0	1	19	19	5	14	1	1	2	3	42
	Y	0	0	0	19	19	0	14	1	1	14	0
	Z	0	0	0	0	0	0	0	14	14	0	0
	T	0	0	0	0	0	0	0	0	0	0	0

to yield the result  $(19 - 5) \times (1 + 2) = 42$ .

- Note that:

- $T, Z, Y$  and  $X$  are used as an evaluation stack, and
- $\uparrow$  is used to signal the end of multi-digit operands.

# Demo and discussion

## Conclusions

- **We're done:** we've understood and implemented enough of a (limited) HP-35 calculator to compute

$$(19 - 5) \times (1 + 2) = 42,$$

*but the main point is what you can do with this next:*

### Example (calculator)

- Has input and output **peripherals** (e.g. keypad, display).
- Responds to simple **commands** from the user:
  - numeric keys specifying what to perform arithmetic on, and
  - control keys prompting arithmetic to be performed.
- Has an **ALU** to perform arithmetic.
- Has one or more **registers** (or accumulators), plus a limited amount of **memory** (e.g., accessed via *STO* and *RCL*, or *M+* and *MR*).

### Example ((micro-)processor)

- Has input and output **peripherals** (e.g. keyboard, hard disk, monitor).
- Executes sequences of simple **instructions** called **programs**:
  - **operands** are what values to operate on, and
  - **opcodes** determine the operation performed.
- Has an **ALU** to perform arithmetic.
- Has one or more **registers** (or accumulators), plus (potentially) many levels and large amounts of **memory**.

## References and Further Reading

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<http://www.hpmuseum.org/>.
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