

Inside HP-19C

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This presentation is intended to show the overall concept and some curiosities of the HP-19C

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The Calculator

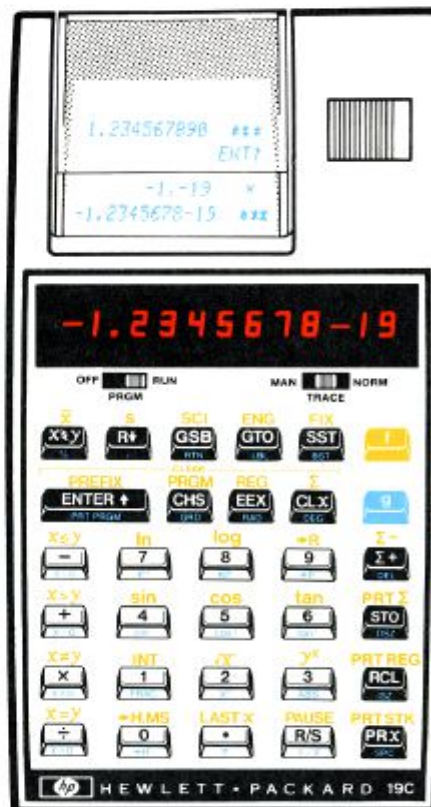
The HP-19C is the only handheld programmable scientific LED calculator with integrated thermal printer which HP ever built . It is the twin calculator of the HP-29C. Both are software compatible with 98 program steps and 30 storage registers and „Continuous Memory“.

Primary storage registers, program memory, displayed X-register, and display format are maintained by Continuous Memory.

Primary Storage Registers			Indirect Storage Registers			Program Memory		
		Address				HP-19C	HP-29C	
R ₀		0	R ₍₁₆₎		16	00		
R ₁		1	R ₍₁₇₎		17	01	64	74
R ₂		2	R ₍₁₈₎		18	02	64	74
R ₃		3	R ₍₁₉₎		19	03	64	74
R ₄		4	R ₍₂₀₎		20	04	64	74
R ₅		5	R ₍₂₁₎		21	96	64	74
R ₆		6	R ₍₂₂₎		22	97	64	74
R ₇		7	R ₍₂₃₎		23	98	64	74
R ₈		8	R ₍₂₄₎		24			
R ₉		9	R ₍₂₅₎		25			
R ₁₀		10 n	R ₍₂₆₎		26			
R ₁₁		11 Σx	R ₍₂₇₎		27			
R ₁₂		12 Σx^2	R ₍₂₈₎		28			
R ₁₃		13 Σy	R ₍₂₉₎		29			
R ₁₄		14 Σy^2						
R ₁₅		15 Σxy						

Automatic Memory Stack

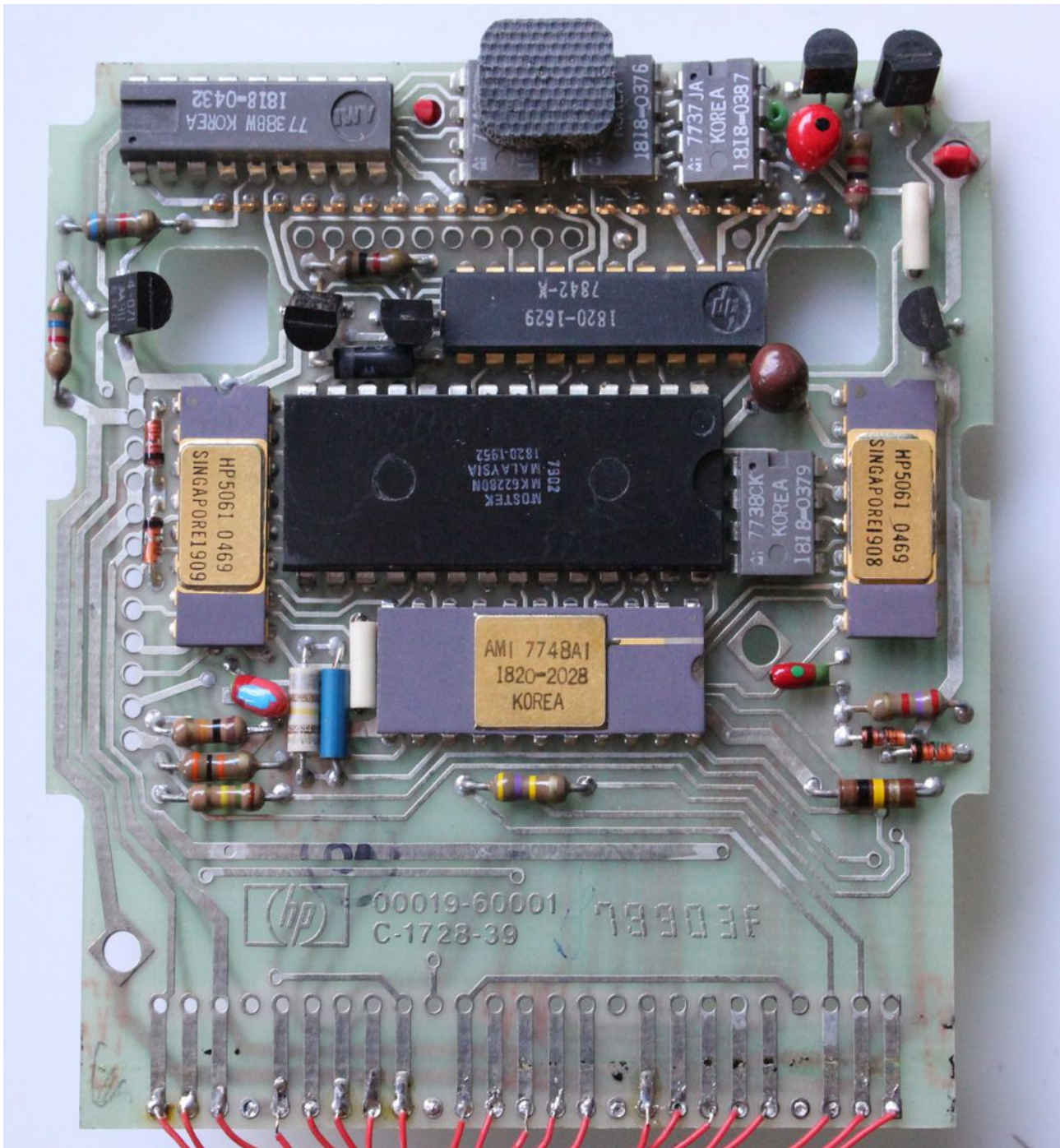
Registers	
T	0.000000 00
Z	0.000000 00
Y	0.000000 00
	Display
X	0.000000 00
	LAST X
	0.000000 00



1.) The Hardware

a.) Mainboard

The HP-19C Mainboard contains the ACT (Arithmetic Control Timing 56-bit Processor), RAM (48 * 56 bit = 2688 bit or 48 registers), ROM (5k*10-bit distributed between four chips) and the PIK (Printer Interface Keyboard), as well as the anode and cathode LED display driver and some transistors and passive components. There are four connectors, which connects the main board to the printer board, the keyboard, and the LED display



There above image shows these components, besides transistors and resistors:

The ACT chip 1820-2028 (22-pin)

The PIK chip 1820-1952 MOSTEK MK62280P (the big one 40-pin)

2x Continuous Memory RAM HP5061 0469

1x normal RAM 1818-0379

3x ROM, 4k (2 ROMs 1k, 1 ROM 2k 2 pages)

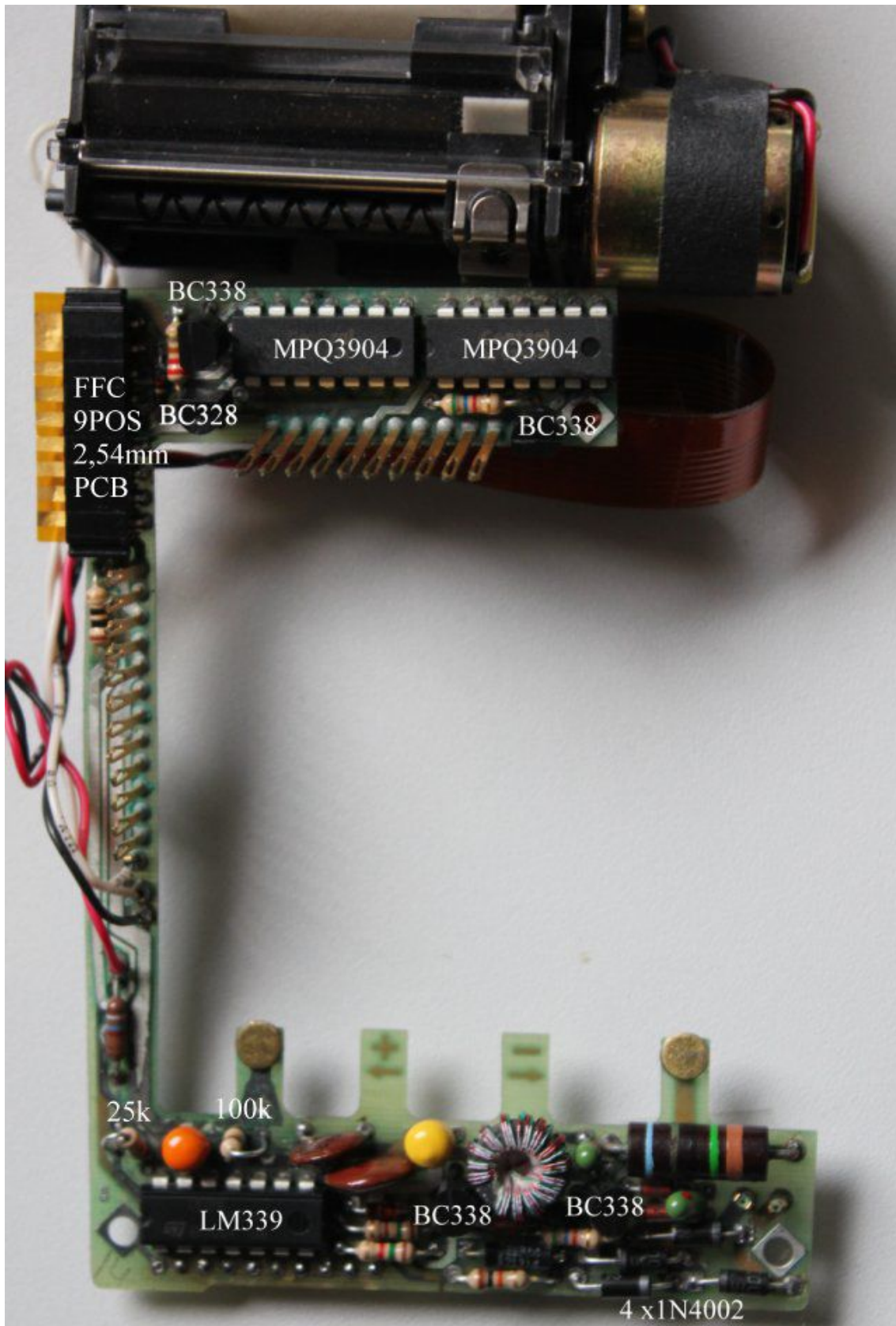
The anode display driver 1818-0432 (contains also 1k ROM)

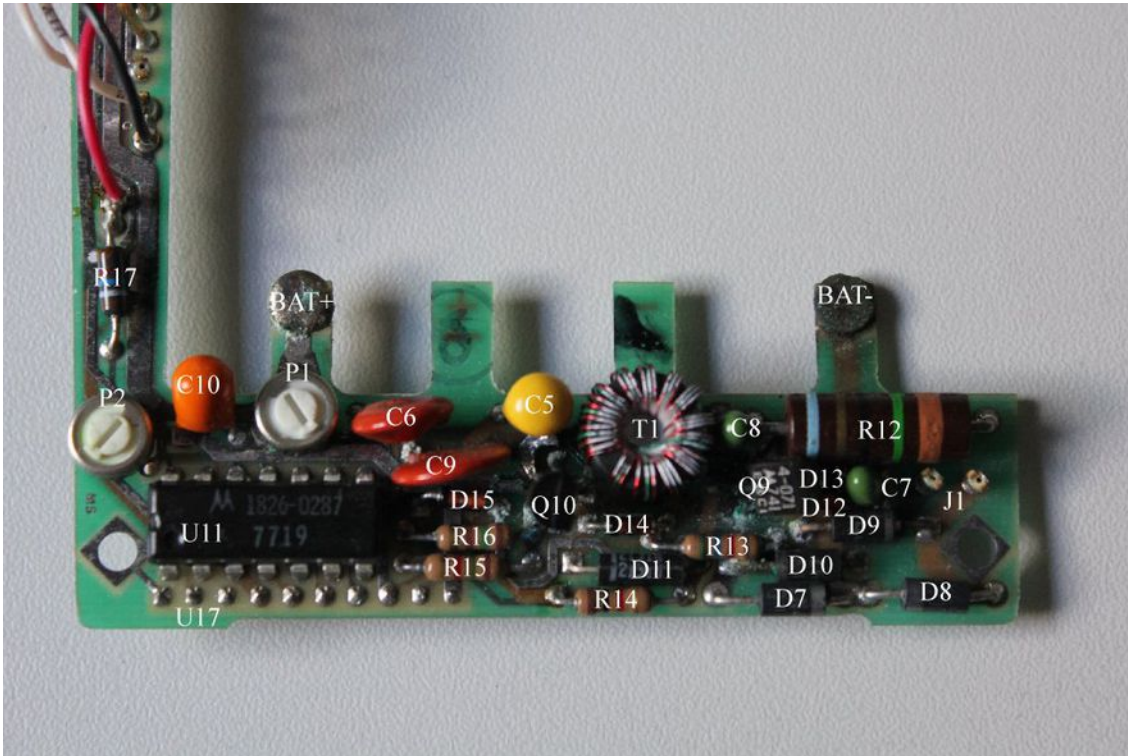
The cathode display driver 1820-1629

Here is another image of a mainboard with the original keyboard connector. Because these 25 pins are just normal wires, they are prone to break or having bad contact.



b.) Power supply and printer board

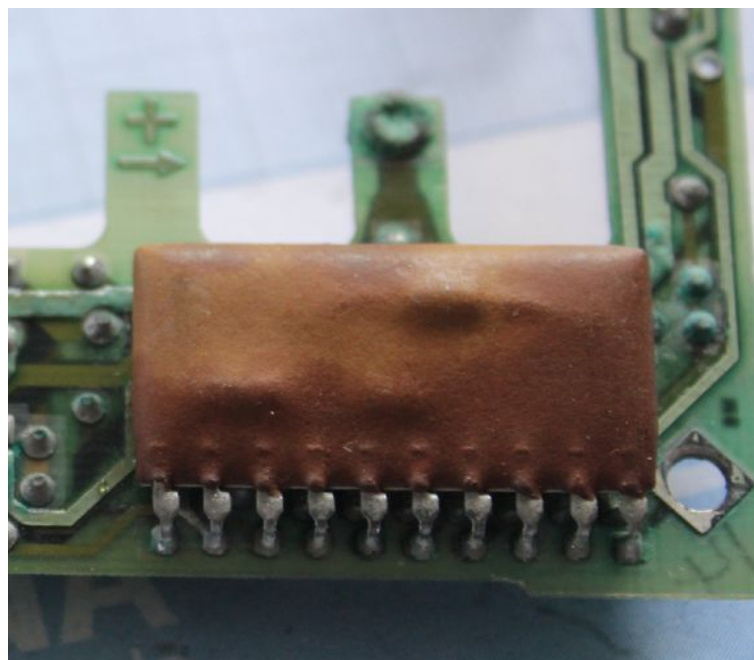




The power supply and printer board surrounds the battery compartment, and can only be removed, by completely disassembling the printer mechanics.

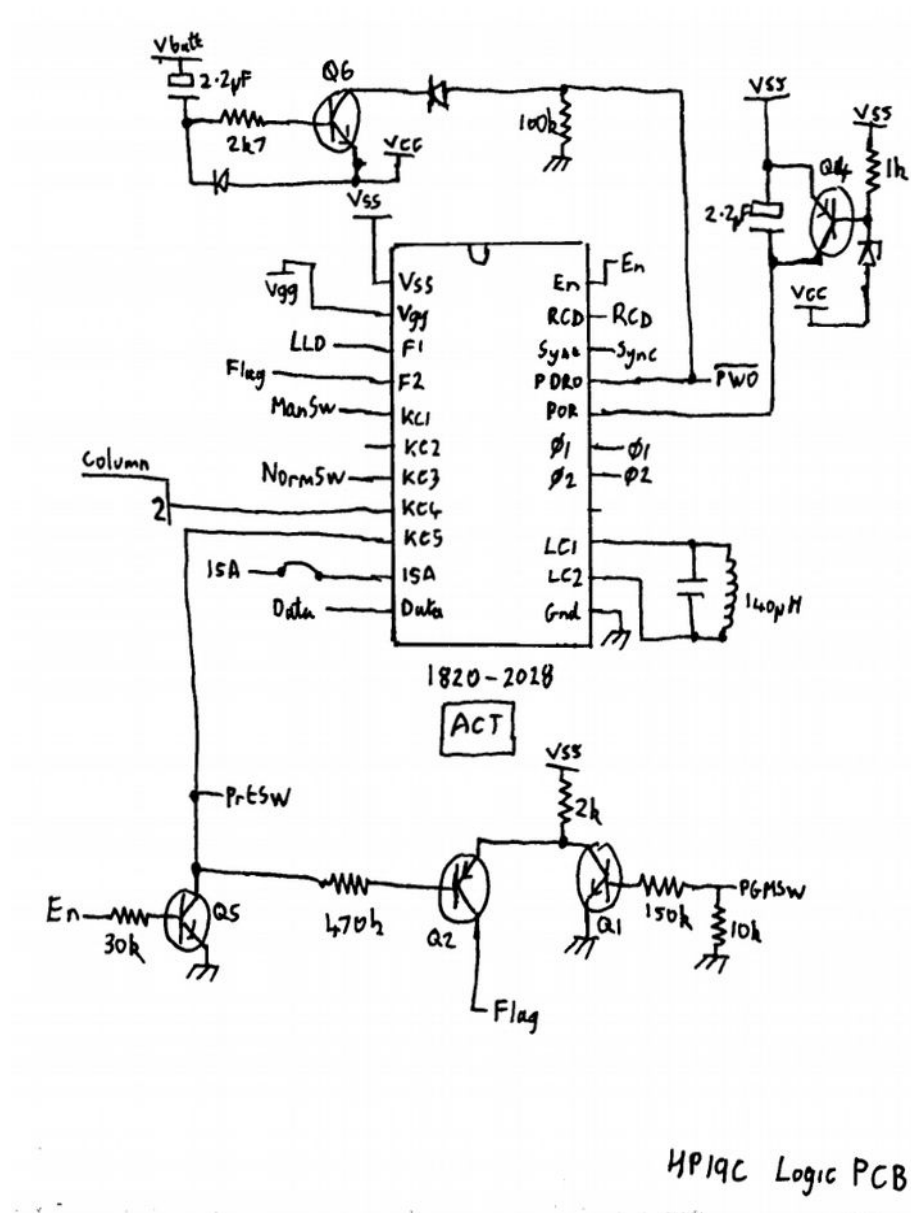
There are three ICs, one comparator LM339 and two 7-transistor arrays MPQ 3904. Even the 9-pin flat ribbon cable connector is still available today from digikey. Other components are resistors, capacitors, diodes, some PNP and NPN transistors.

The „Power Supply and Printer board“ can be completely new assembled by todays available components, except for the yellow/brownish ominous network circuit located on the bottom side.

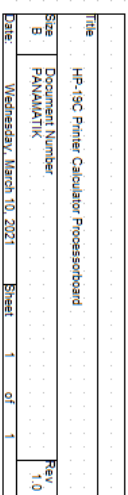


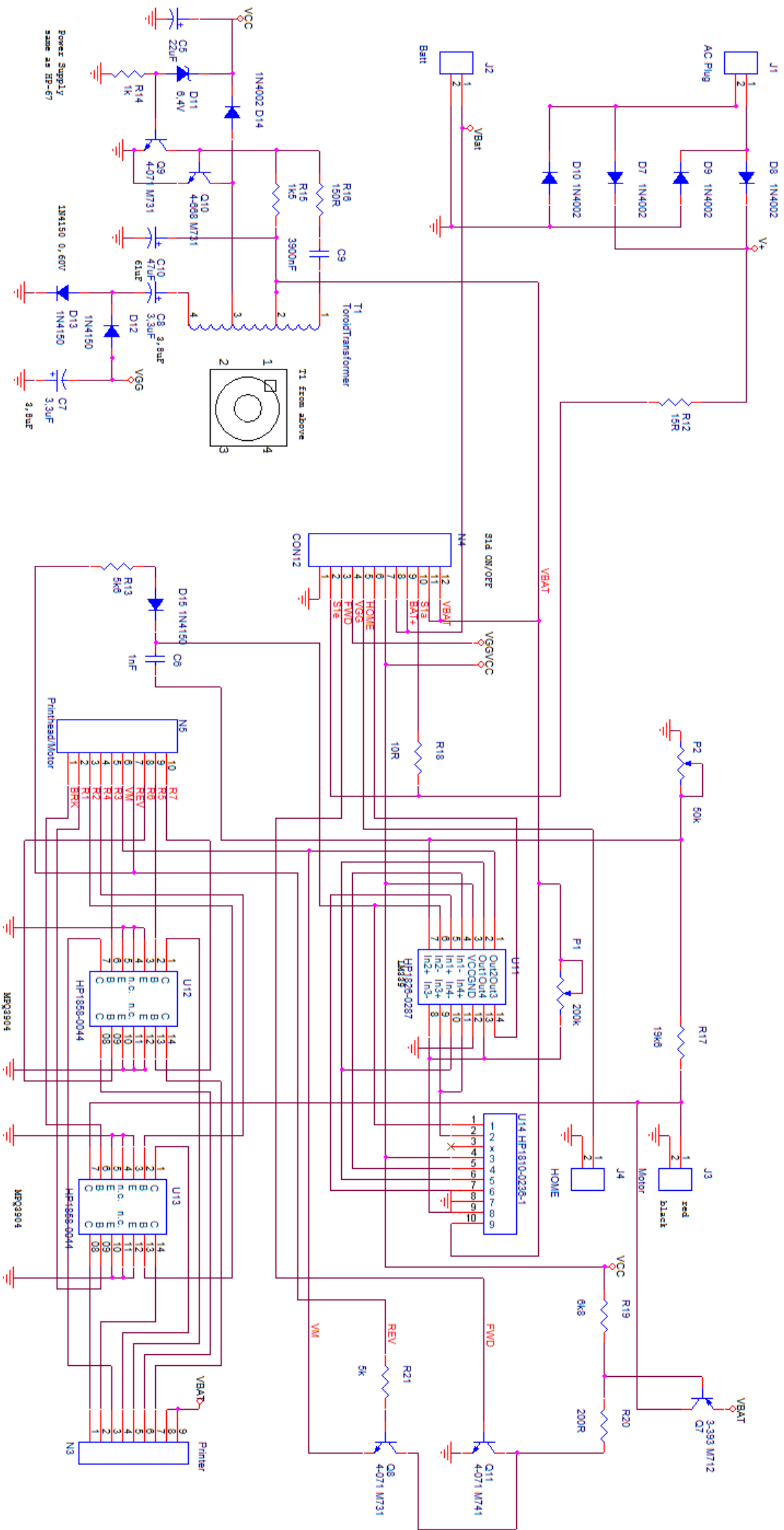
2.) Schematics

There is an accurate hand-written schematic from Tony Duell available (9 pages). Here is a small excerpt.



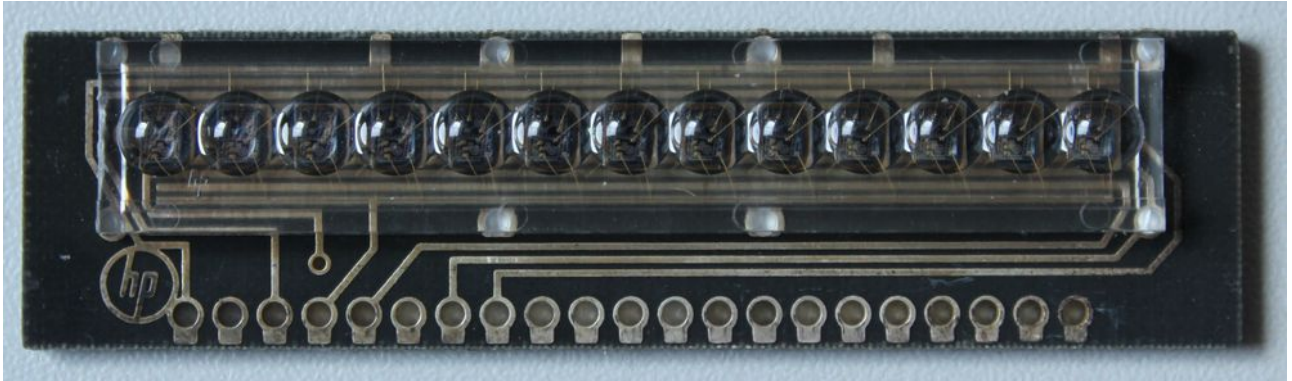
The following HP-19C Schematic is reengineered by myself from the PCB board traces, but I do not take responsibility more than 98% correctness.





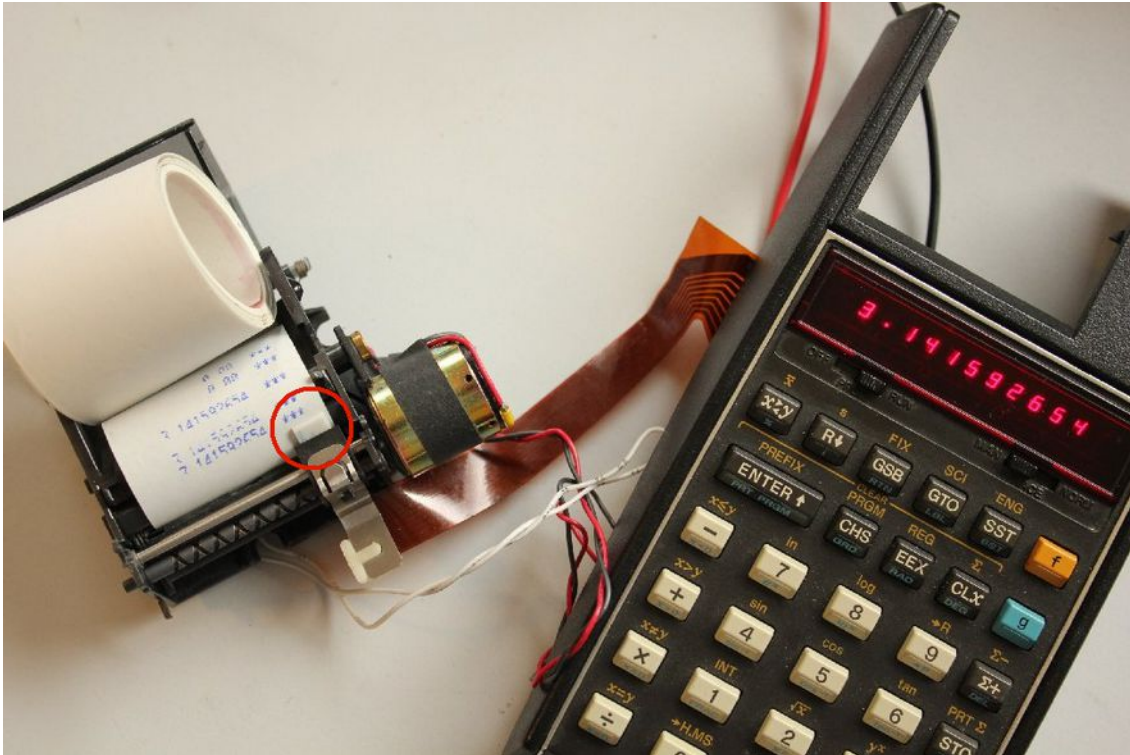
3.) LED Display

The HP-19C has a 13-digit LED bubble display, very similar to the HP-25 display but with one more digit.



Interestingly the pinout is compatible to the 20-pin 12-digit Woodstock display, it just has one additional pin for digit 13. If the display is defective or lost, it is nearly impossible to find a replacement, but there is the possibility to plug in a common HP-21/HP-25 woodstock display, for the price of a missing rightmost digit.

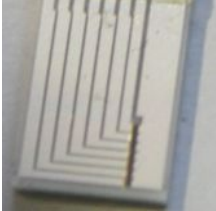
4.) The Printhead



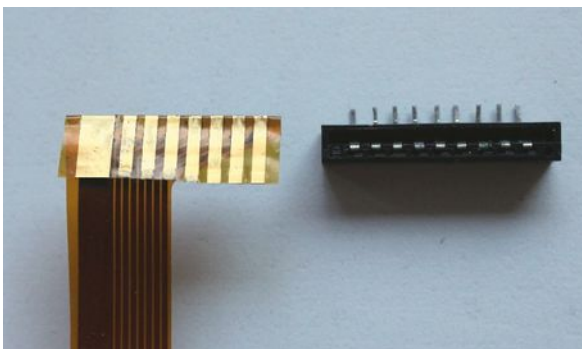
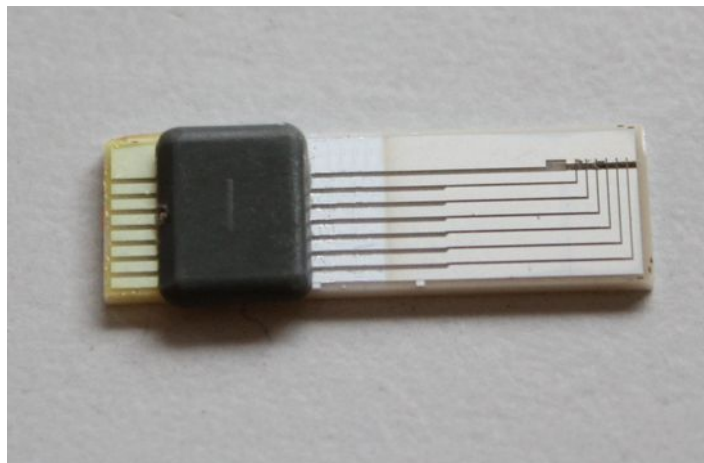
The printhead is a small white ceramic plate with 7 heating elements. Each has a resistance of about 12-14 Ohm and is driven by a pulsed signal via transistor array. The common pin is directly

connected to 5V battery plus. If a heating element is driven permanently it will overheat and burn very quickly by the high 350 mA current.

To avoid sudden current rise during printing, the elements are not switched on at the same time, but some ms shifted, therefore they appear always as *italic* characters.



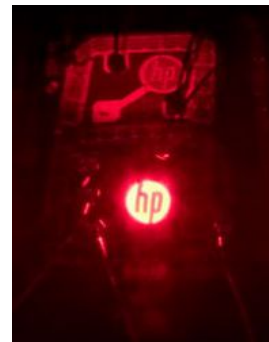
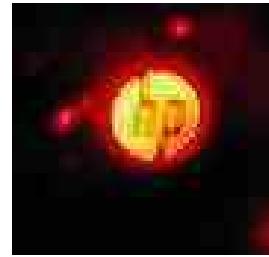
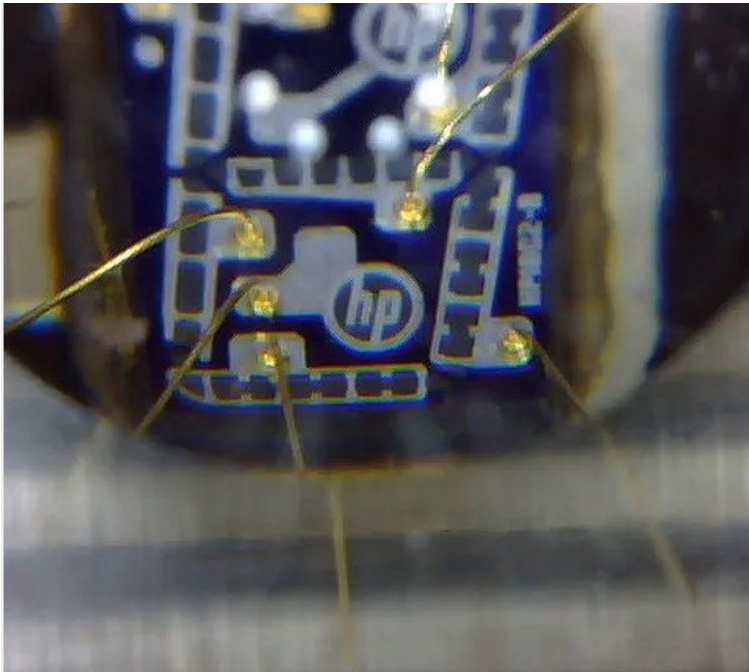
The ceramic substrate has 8 aluminium traces, they are connected to a brown flex ribbon cable by very small bond wires. The other end of the flex cable is connected to a 9-pin through hole connector. Removing the flex cable from the connector destroys easily the contacts, You must insert a thin plastic sheet to remove the cable without damage.



Today's thermal printers don't have a moving printhead, but have many thermal elements for the whole print line. This eliminates the need for the complicated motor mechanics and makes them also much faster.

5.) Curiosities

a.) *The LED display HP-Logo in the decimal dot.*



The HP-19C has a 13-digit LED bubble display.

As we know by ourselves, engineers do want sometimes to make a joke or at least hide an easter egg in their products. One of the most famous easter eggs can be found in the HP-19C LED display as a small HP Logo, which is hidden in the decimal dot of each digit. Only a magnifier glass or a microscope can reveal the Logo.

An even more hidden easter egg can be found in the anode display driver chip 1818-0129 of the Woodstock HP-21 calculator. I mention this because it is strongly related to the HP-19C logo easter egg. The Woodstock display driver has a total of 5 alpha characters, which can be displayed, additional to the 10 number digits. In the HP-21 only three are really used for displaying the text „Error“, which appears by dividing by zero. The remaining two digits will never be used by the HP-21 operating ROM code. During developing the „new ACT“ chip, I was able to force these hidden/unused characters to be displayed, and to my surprise the letters „H“ and „P“ appeared!

Later in the HP-25 model, the same engineers had the idea to show the Text „OF“ for number OverFlow, which should be displayed when the arithmetical result overflows i.e. was greater than $9.999999999 \cdot 10^{99}$. Therefore they needed the new letter „F“. They decided to design another anode driver chip and replaced the letter „P“ with „F“.

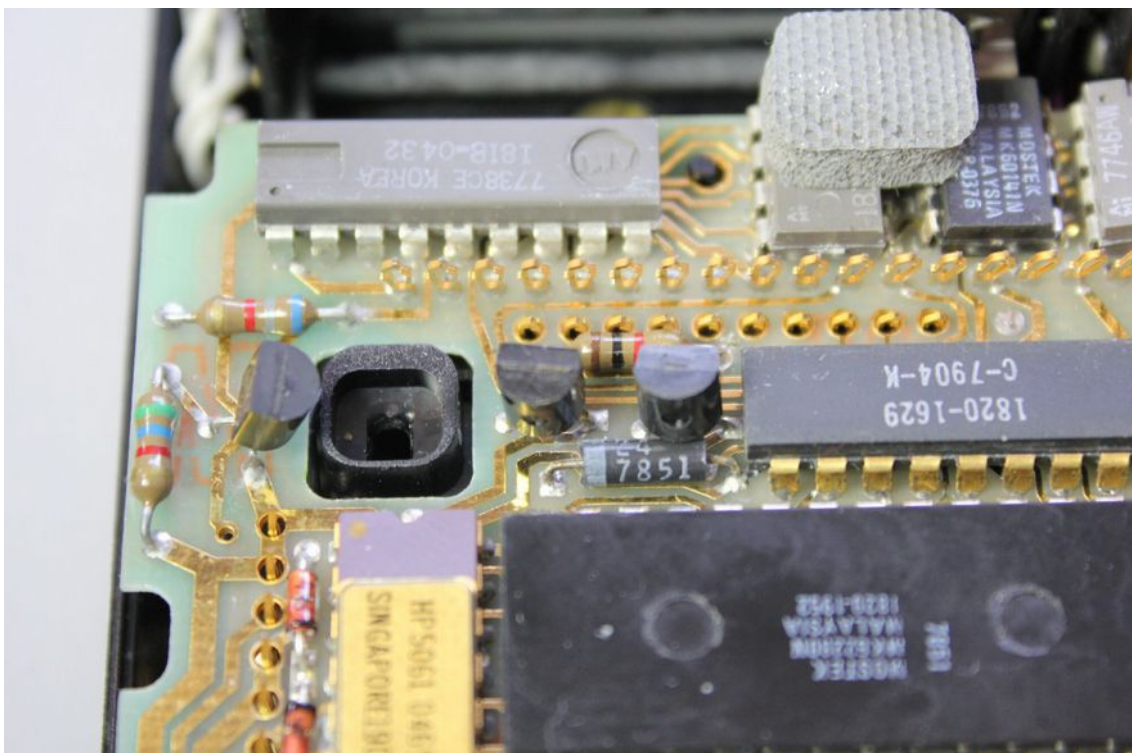
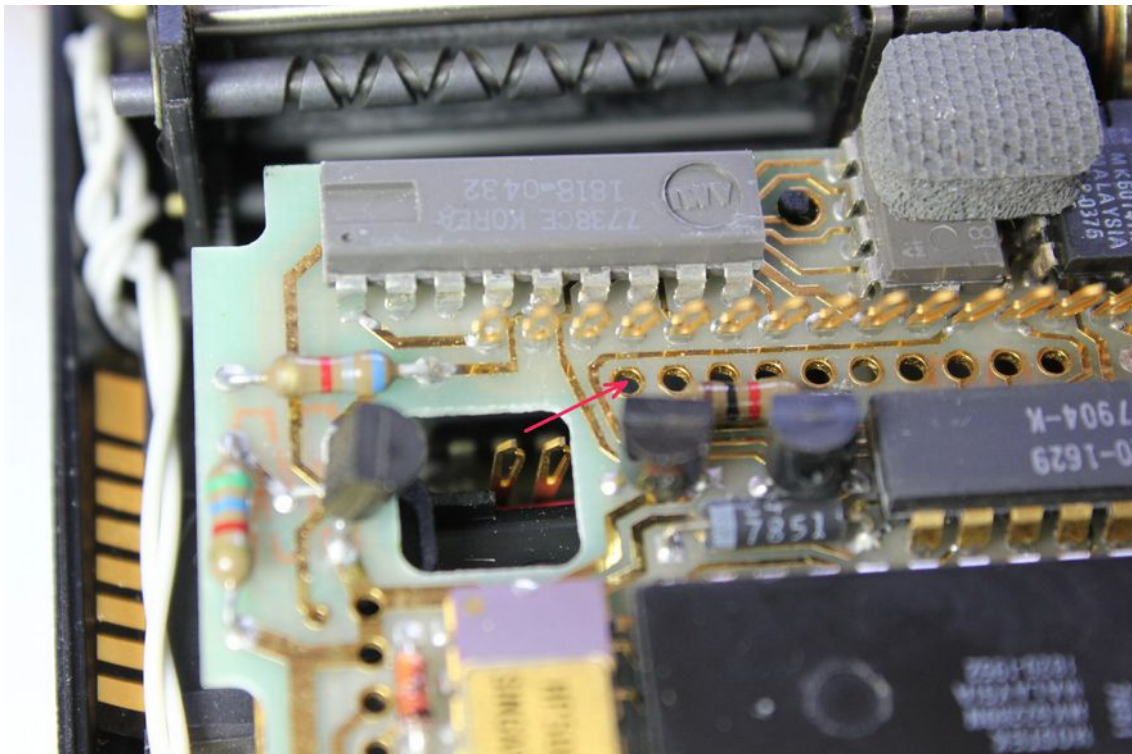
What would Mr. Packard have said, if he had known of this offence against him. It is rumoured, that Mr. Hewlett himself instructed the engineers to sacrifice the letter „P“ and not his own letter „H“.

But this problem settled anyway with the introduction of the HP-67 because it needed to show the letter „C“ for „Crd“ to insert a magnetic card and they sacrificed also the letter „P“ !

b.) Closing the case is a pain.

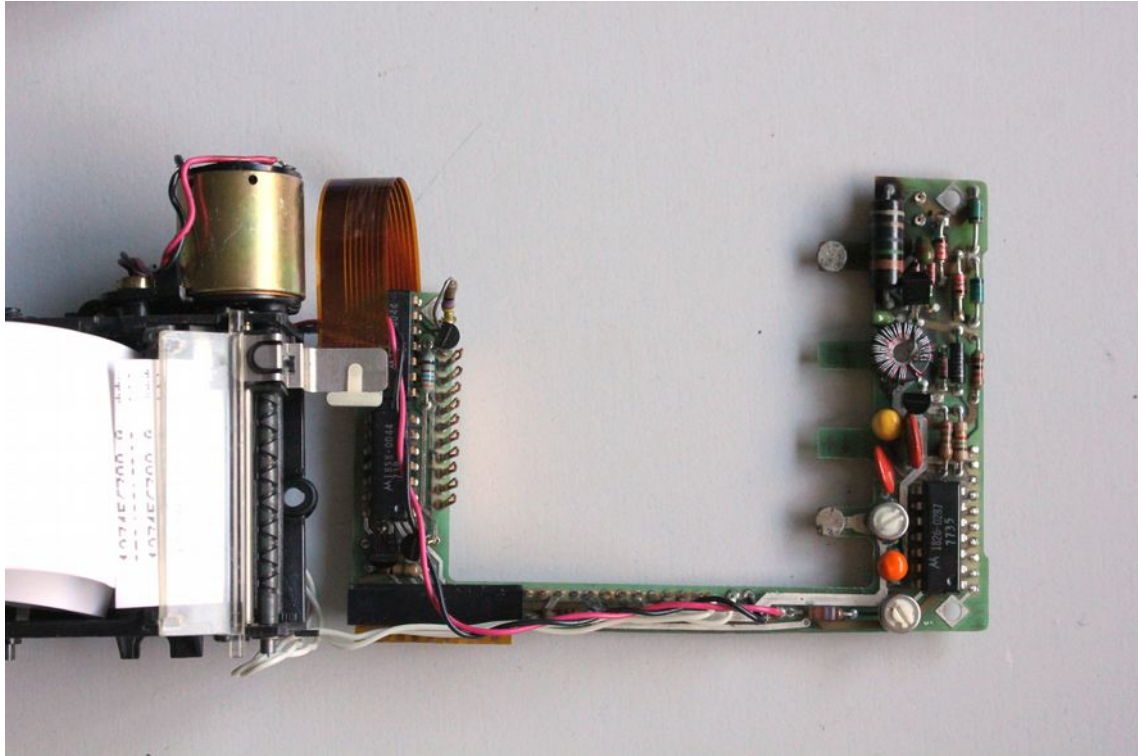
I will never understand, how they managed to mass produce this calculator. I need 1/2 hour just to close the case. And while doing so, it is easy to bend or even break some of the golden prongs, which connect the two PCBs. You have to fiddle the boards somehow together and hope that all fits.

The best trick I found to simplify combining the two PCB boards when assembling the HP-19C is: Remove the LED display, then first stick the horizontal contacts by looking through the hole to the left, for getting their actual position, then moving the short distance to the holes. The following step is, also stick the vertical pin contacts, which is now rather easy.

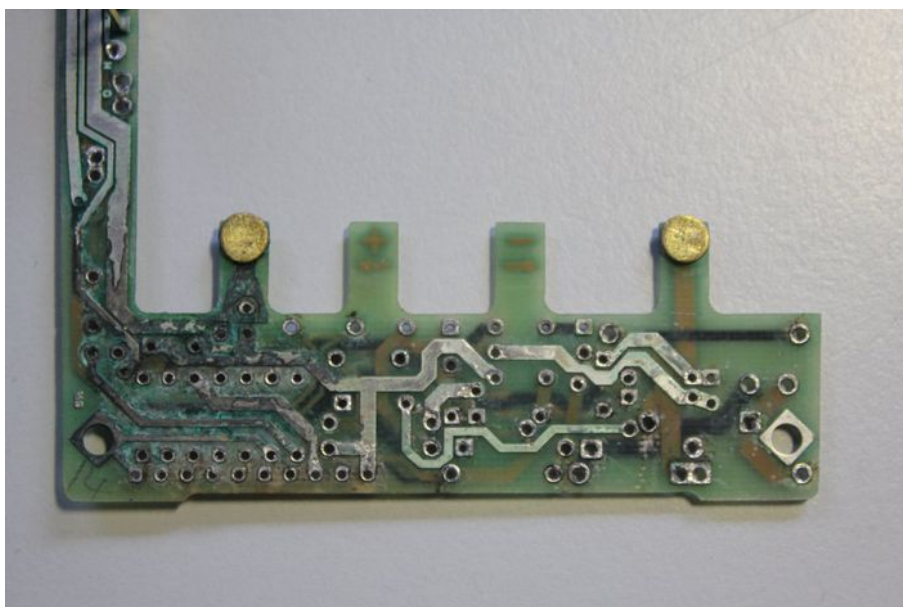


c.) A Multilayer Board!

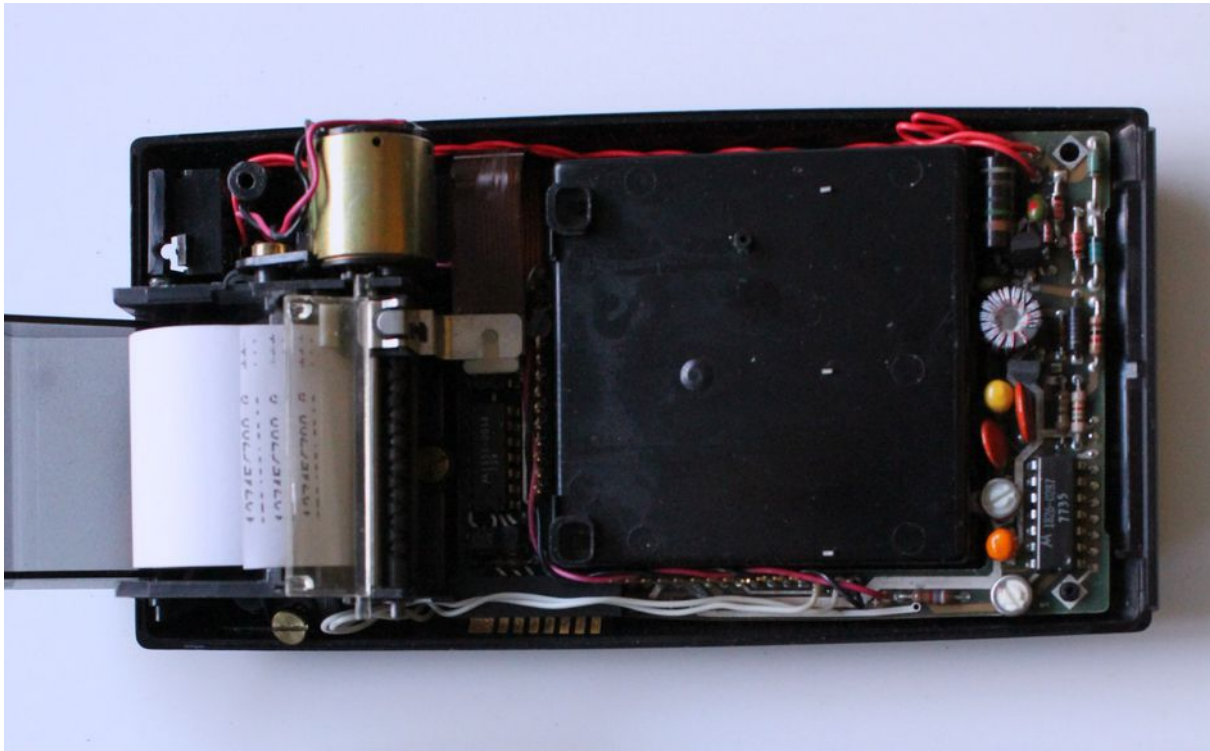
The imposed pressure to the engineers by the project management to fit all the electronics and the printer into the small case must have been enormous. For the first time they used a multilayer board for a pocket calculator. This allowed to place the components of the power supply and printer control board more dense together as you can see in the image below.



The printer board has three signal layers: Top, Bottom and middle layer. Even after I removed all components from the board it was still not easy to reengineer the schematics. The quality however was very high, removing all components was not destructive and I was able to reassemble the board and it was functional again.



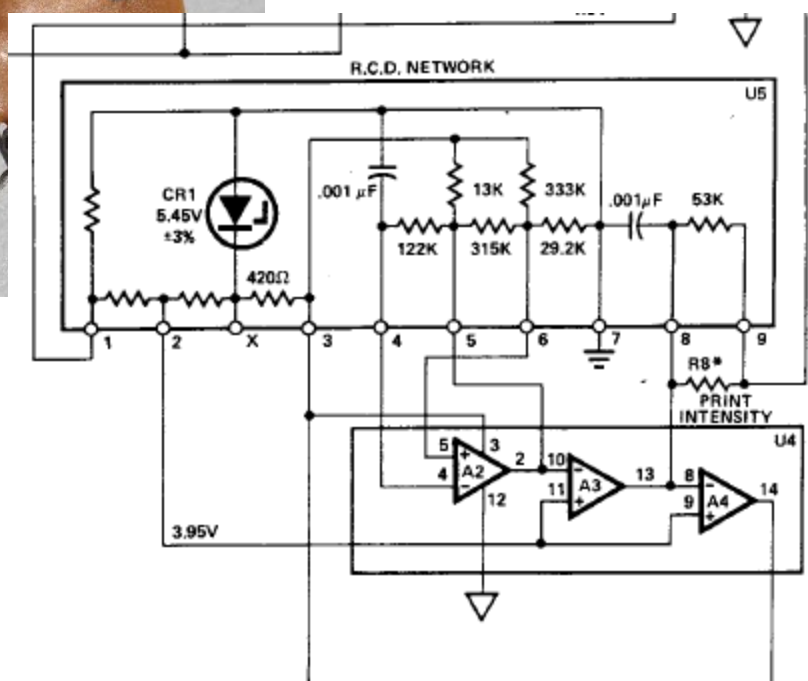
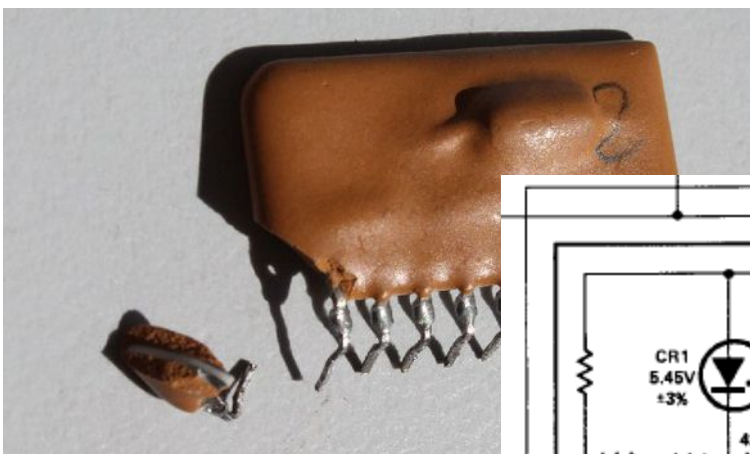
The thickness of this multilayer PCB nevertheless is only 0,5 mm! Normal PCBs are 1,5mm. The reason is strange: For assembly of the calculator the board had to be flexible.



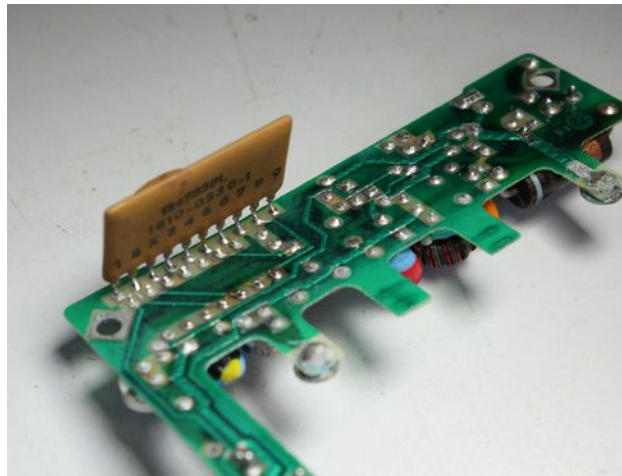
If you want to remove (or insert) the printer PCB, you first have to completely remove the printer and then you must bend the whole PCB about 2 cm upwards over the battery compartment, until you can move the battery contacts horizontally out of the openings.

d.) The mysterious yellow-brown thick film component.

This special circuit is the only passive component, which cannot be replaced by today's components if it is broken. Clearly it can be seen, that I have broken it. It is a R.C.D. network (Resistor, Capacitor, Diode). Theoretically, it can be reconstructed by separate components.

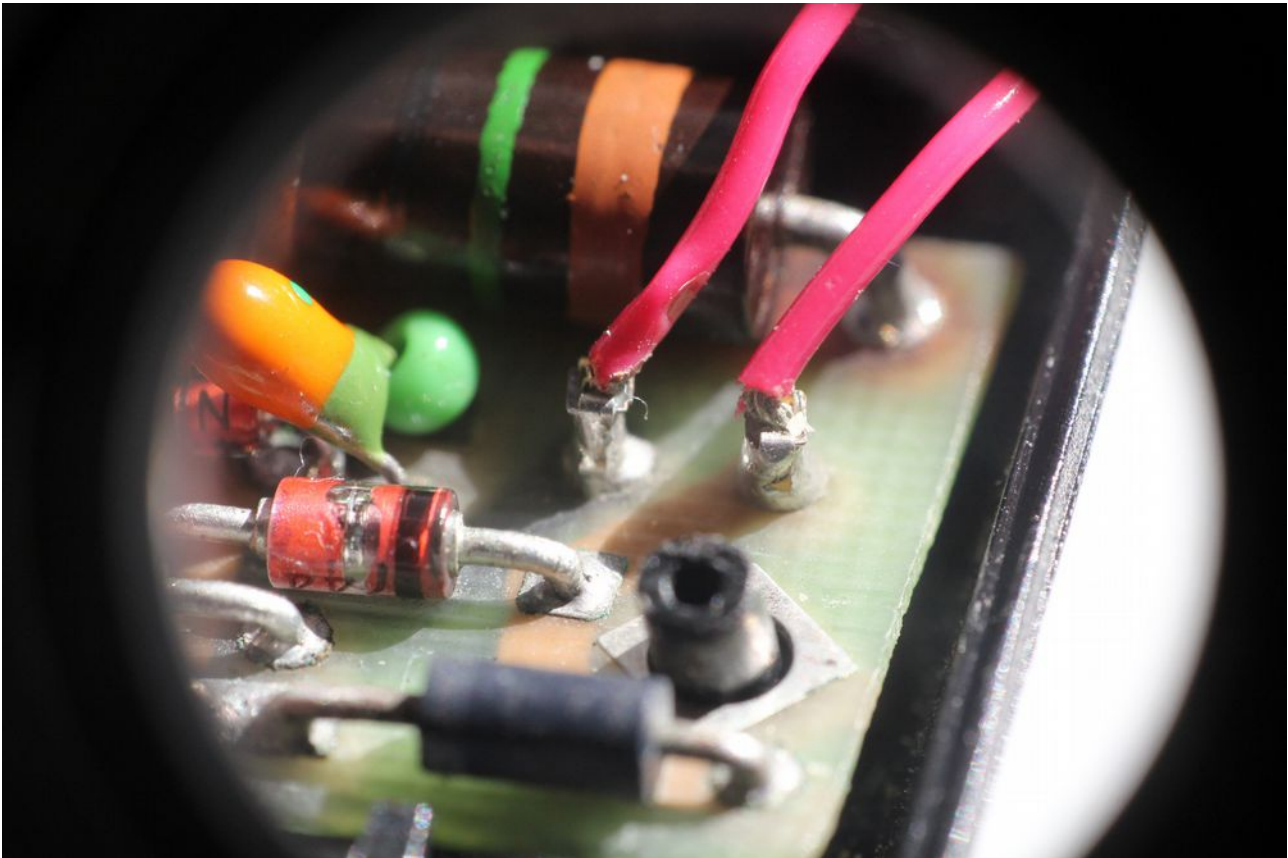


My strong assumption why this components exists, is, that even with three layers there was not enough space on the PCB board, therefore these discrete components were packed into an „Integrated circuit“ and then could be soldered on the bottom side of the board, to take the last available space.



Inside the component is a ceramic substrate where the resistor carbon films are directly coated onto the substrate and capacitor and diode elements are added. These components are used to dimension the comparators, as seen in the schematic, which control the print intensity and motor speed.

There are six individual wires, which must be fiddled into six single pin sockets, see two of them in the image below.



The three special flat brass screws, which hold the printer chassis, need ten tries, before they fit into the thread. They fall at least three times off and hide themselves somewhere in the case below some other components, or under the table.

Some HP-19C cases have an anti-theft security ring, which makes it even more problematic to close the case.

e.) Even ultra low profile socket for the ACT has not enough space.

When I had the idea to replace a defective HP-19C ACT by my „new HP-19C ACT“, which still doesn't exist, I came across the problem, that there was no space left above the ACT chip, not even 1/2 mm. The chip must be soldered in without socket, otherwise the case cannot be closed. Chapeau for this perfect measuring even without CAD.

This was one of the reasons (or excuses) why I didn't pursue this project any further :-)

f.) Why so many transistors?

The reason is quite simple! The discrete transistors serve additional functions, which were not

achievable by the integrated circuits. Because it was decided to use the existing ACT arithmetic chip, which was not designed for the HP-19C, but for the HP-2x series, there has to be constructed additional functions around it, like switching the ROM pages and reading the printer switch by some very tricky circuit ideas.

g.) The mysterious fifth ROM page and the PRGM/RUN switch

In 2015 I did not own a working HP-19C, only a wreck, which was stored in sea water in a sunken vessel, where all ICs including the ROMs and the display were totally destroyed and completely dead. But I wanted to read the ROM code, which was not yet extracted by anyone. Therefore I borrowed a HP-19C from Harald Pott, who was living not far from my home. I could then read 4 ROM pages by injecting all possible 12-bit addresses 0x0000-0x03FF and read the opcodes serially from the ISA line. Indeed most of the code was identical to the HP-29C, because they were twin calculators. But Eric Smith claimed, that the HP-19C had 5k ROM! I didn't know whether this was true, because there were only 4 ROM chips. Where was the 5th ROM? I experimented with injecting the „Bank Switch“ Opcode 1060, which was introduced for the HP-34C and HP-67 to switch between different 1k pages, but nothing worked. One year later I had a new idea, at least I had increased my knowledge, because I found that one pin of two ROM chips was connected to an output of the ACT processor. I again borrowed the calculator from Harald and tested the ROM contents depending on the level of this ominous pin. And voila, this was a bank switch input signal, an additional address line, this ROM was a hybrid between serial and parallel addressed memory!

After having extracted the complete HP-19C ROM code, I was able to create the first HP-19C emulator for windows, which was hard work for many months.

Here you can download the HP-19C emulator and the corresponding user manual

<http://www.panamatik.de/HP19Emulator.zip>

<http://www.panamatik.de/HPEmulator.pdf>

h.) Why the HP-19C uses a 4x8 key matrix instead of 5x7 like all the Woodstock calculators?

The HP engineers developed the ACT chip for reading of up to 35 keys in a 5x7 matrix, the chip has 5 dedicated keyboard input pins, which were multiplexed with 7 rows. Why not read the 31 buttons of the HP-19C with this interface?

After some consideration we will understand. With the HP-97 desktop calculator, which should become 56 keys, a 35 keys interface was not longer sufficient. Clearly the ACT was not capable of reading so many buttons. This led to the development of the PIK chip, which was especially designed for the HP-97 calculator and assisted the ACT chip in reading more keyboard buttons - and of course they also included a thermal printer interface.



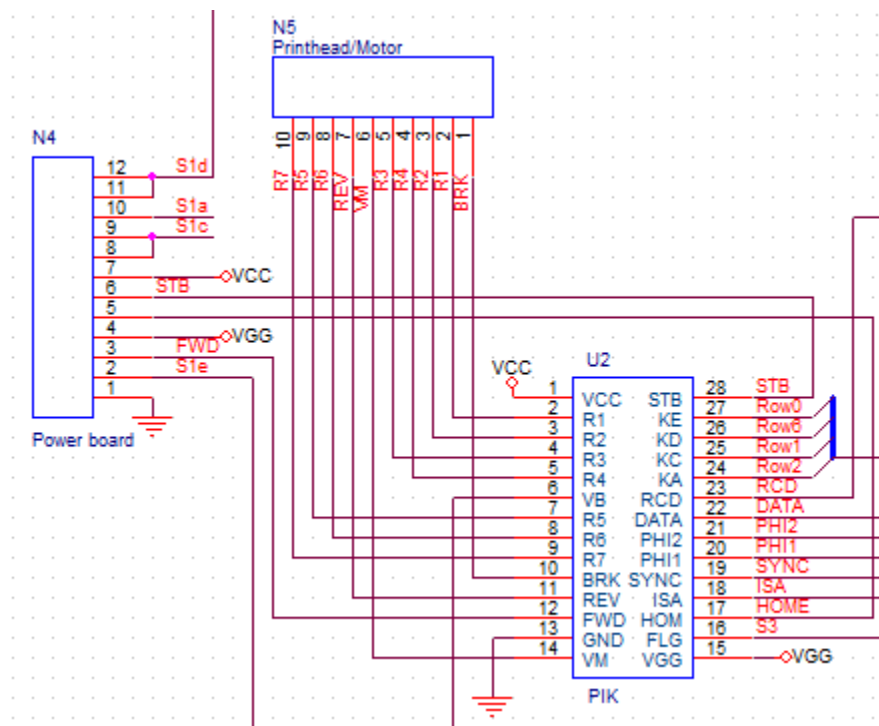
Much of the design of the HP-19C was based on using existing chips. The common cathode driver chip 1820-1382 of all Woodstock calculators was designed to display up to 14 digits and could simultaneously scan up to 14 keyboard rows. This chip should also be used in the HP-97. The PIK chip therefore became 4 keyboard input pins, which were multiplexed by 14 rows, which together could read 56 buttons.

Because the HP-19C also had to use the PIK chip, because it was needed for the printer, the keyboard had to be organized in 8 rows and 4 columns. $4 \times 8 = 32$ buttons, where 31 were really used.

i.) The PIK chip

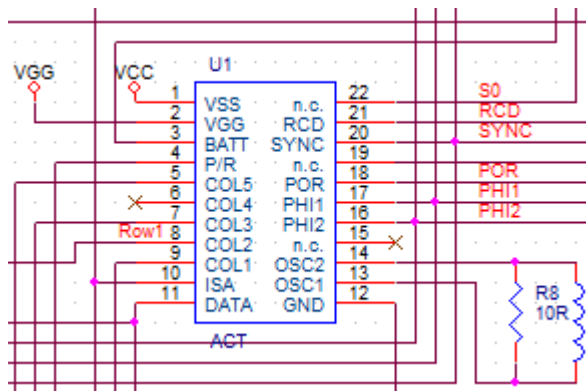
The purpose of the „Printer Interface Keyboard“ chip is to scan a keyboard matrix with up to 64 buttons and buffer up to 16 keystrokes, without losing keystrokes even while a calculation like SIN COS etc. is executed. This would not have been possible with the ACTs keyboard interface. It guarantees very effective fast keyboard entry, with up to 10 keystrokes per second for multiple additions, usually performed by a young japanese female personal assistant with exceptionally keyboard skills.

The second purpose is to control the printer pixels and the motor speed. The motor can spin Forward and Backward, however Backward movement is not used in the HP-19C (but used in HP-97). This simplified the motor controller components.



The 28-pins of the PIK chip and their meaning.

k.) The strange way how to detect, whether a key is hold down.



What you can see in the schematic above: The ACT chip with its keyboard interface COL1 - COL5. The five Keyboard Columns of the ACT chip are abused to read the MAN/NORM/TRACE switch and check whether the R/S and SST button are pressed.

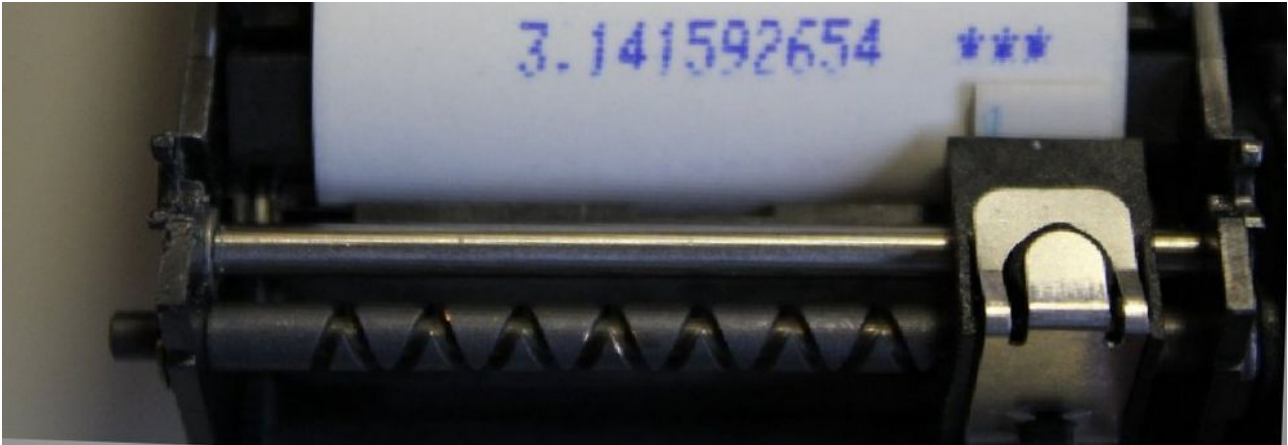
Although the PIK chip can buffer up to 16 keystrokes, it cannot tell whether a key is hold down. Because for most buttons it is not necessary to know whether it is hold down, only keyboard Row 1 is connected to the ACT keyboard interface, because it contains the R/S and SST key!

Row	1	2	3	4	5	6	7	8
0	EEX	CLX	-	g	$\Sigma+$	7	8	9
1	GTO	SST	---	f	PRX	0	.	R/S
2	X \leftrightarrow Y	Roll	x	GSB	RCL	1	2	3
6	ENTER	/	+	CHS	STO	4	5	6

For reading the Printer slider switch, a keystroke is simulated by setting COL1 to Low, when S0=High via a transistor Q5. Because S0 has a double purpose, switching the ROM page and reading the sprinter switch this leads to a curiosity.

The slider switch may only be read when the program code is running within the lower ROM chip with single ROM page, otherwise the program will stall.

l.) Moving the printer Motor only in one direction.

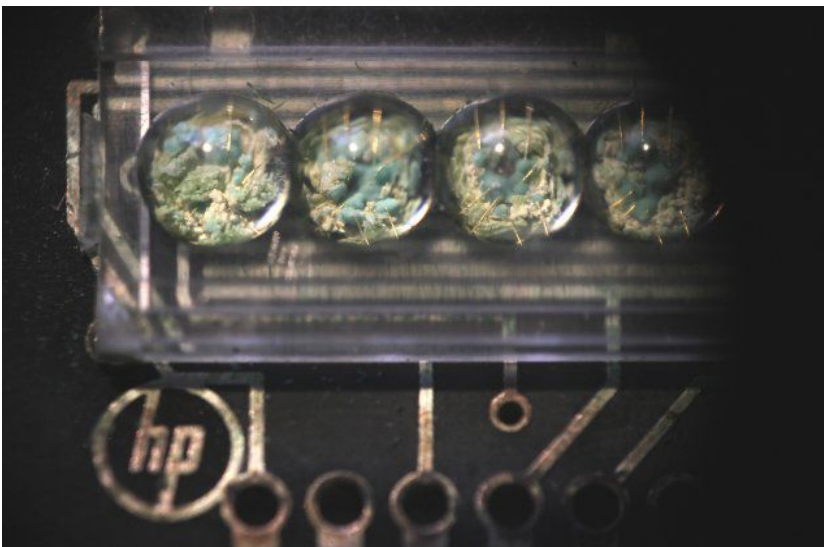


A special mechanical wheel construction, as seen above, allows to move the printhead forward and backward without reversing the motor. When the motor rotates permanently the printhead moves back and forth without mechanically blocking anywhere. To output a print line, the motor is just started by switching transistor Q7. However it must move the whole distance to the left before it can return to the home position. This is less effective as to reverse the printer motor as soon as the last visible digit is printed, like the HP-97 does, especially for short lines like **0.00**. But at least the HP-19C hardware uses a little optimization: when the last visible digit is output, the motor accelerates to full speed until it reaches the HOME position.

The print speed (and thus the width of the characters) is regulated by a comparator circuit, which gives feedback about the motor speed by the VM signal. If this signal is Low the FWD (Forward) PWM signal reduces its duty cycle, which slows down the motor. If the REV (Reverse) signal is output by the PIK transistor Q8 bypasses the comparator circuit and sets the VM signal permanently High, which causes the motor to go full speed. After having reached the Home switch, the PIK issues the BREAK signal which stops the motor immediately.

All this motor regulation logic is done by hardware inside the PIK chip.

m.) Have you ever seen a HP-19C display like this?



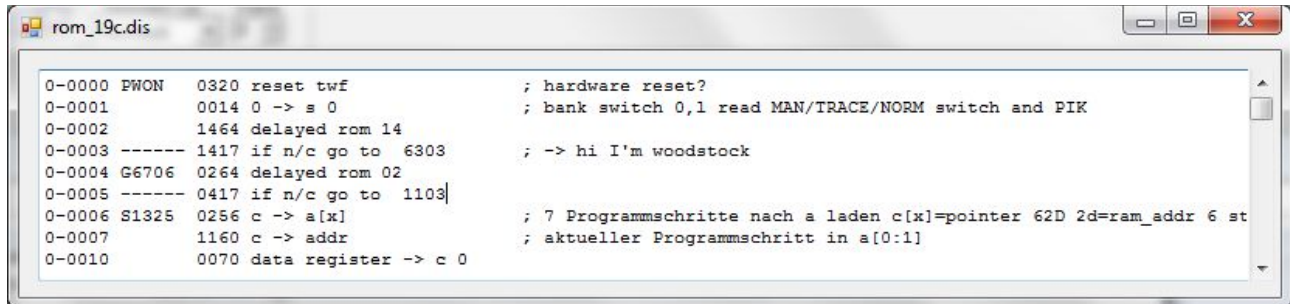
This image is synonymous for the overall condition of my first HP-19C calculator, which I acquired from ebay for a bargain.

When I ever will finish my work on the HP-19C ACT and PIK replacement circuit, then even this calculator will be repaired and have a calculator life again.

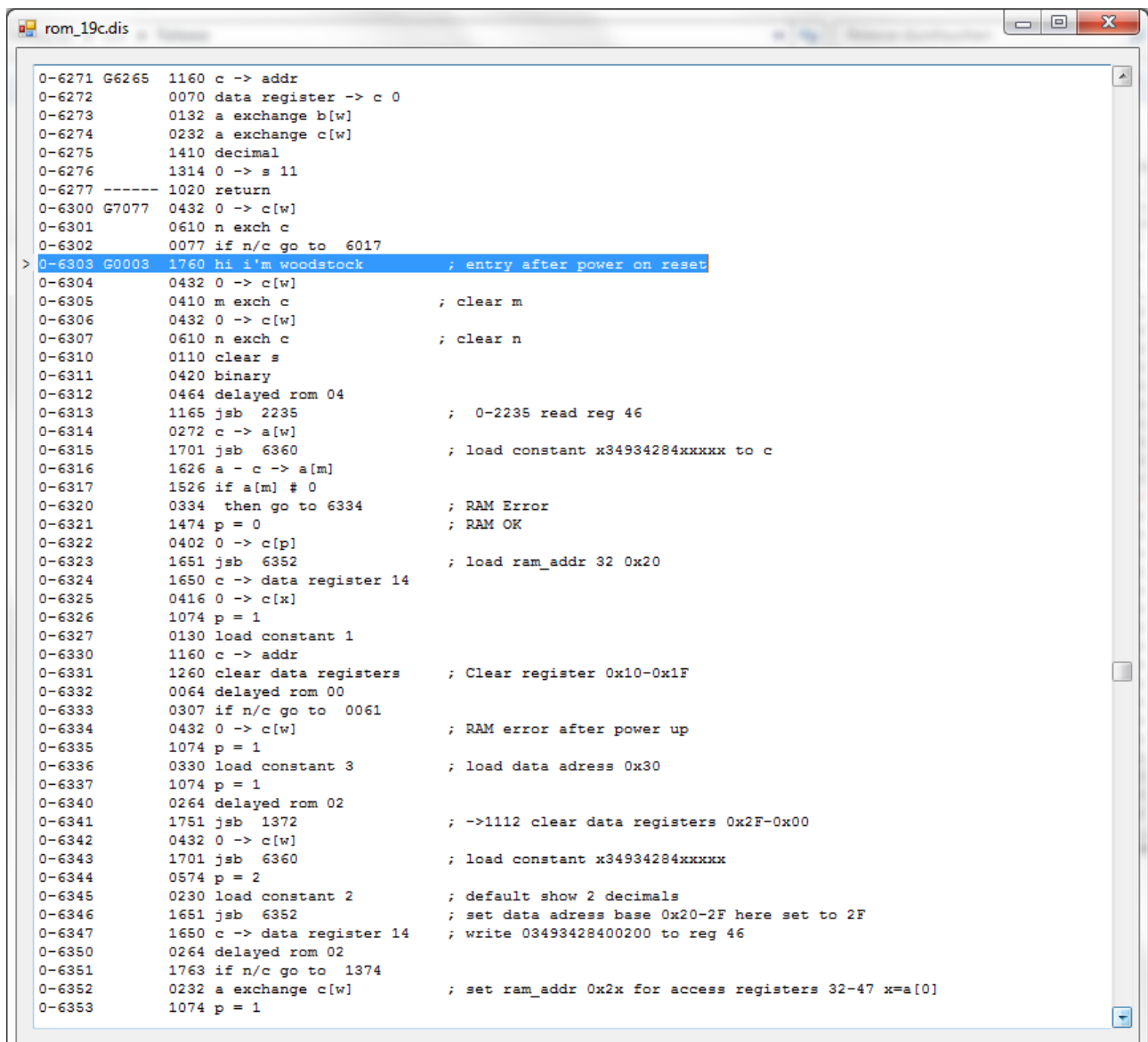
6.) Software

The HP-19C has five pages of ROM code (5*1024 10-bit instructions). The HP-29C has only four pages. Page 0 is different, the next three pages are exactly identical, and page 4 of the HP-19C contains only printer related code.

a.) Power On Reset

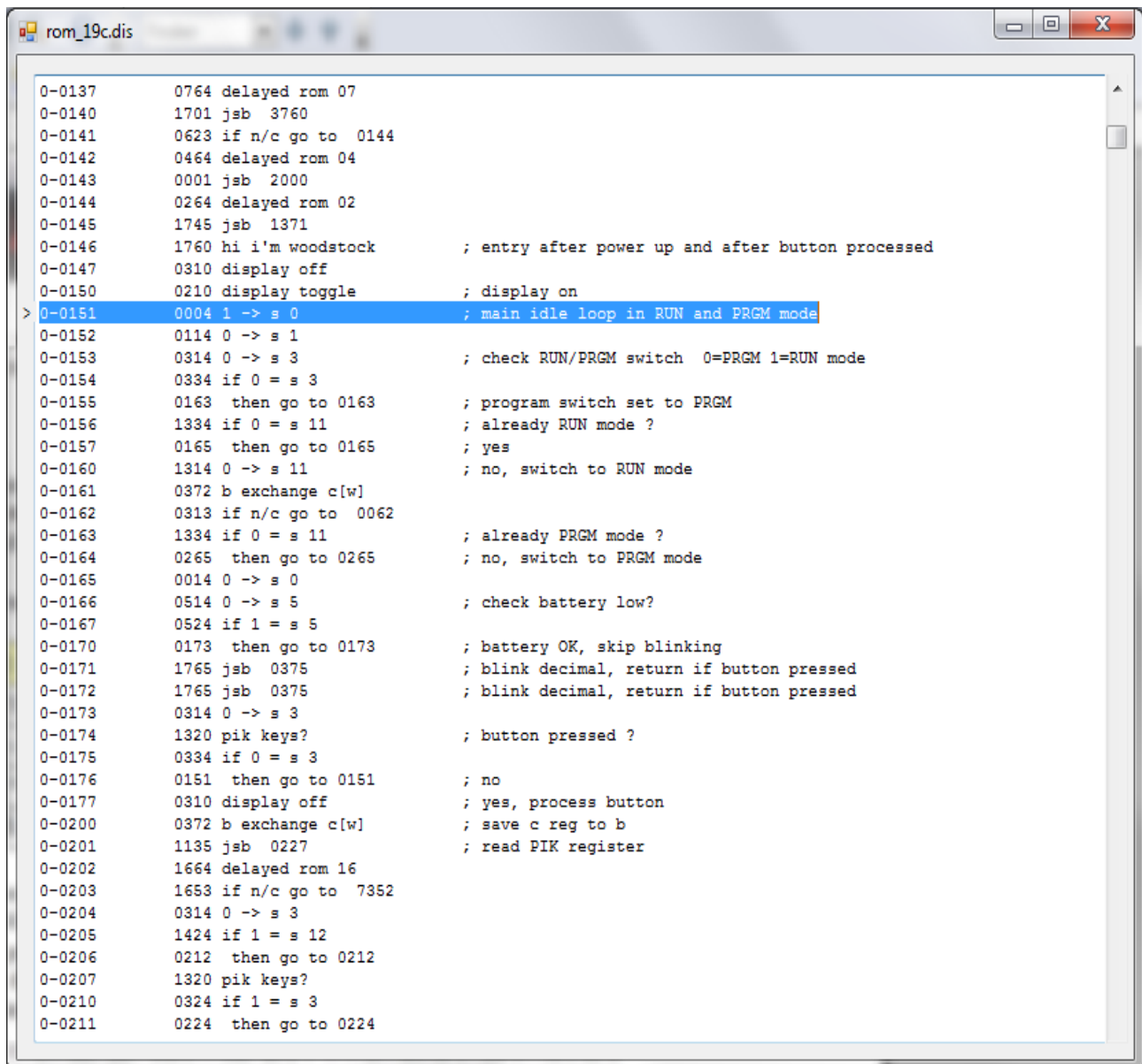


```
rom_19c.dis
0-0000 PWON 0320 reset twf ; hardware reset?
0-0001 0014 0 -> s 0 ; bank switch 0,1 read MAN/TRACE/NORM switch and PIK
0-0002 1464 delayed rom 14
0-0003 ----- 1417 if n/c go to 6303 ; -> hi I'm woodstock
0-0004 G6706 0264 delayed rom 02
0-0005 ----- 0417 if n/c go to 1103
0-0006 S1325 0256 c -> a[x] ; 7 Programmschritte nach a laden c[x]=pointer 62D 2d=ram_addr 6 st
0-0007 1160 c -> addr ; aktueller Programmschritt in a[0:1]
0-0010 0070 data register -> c 0
```



```
rom_19c.dis
0-6271 G6265 1160 c -> addr
0-6272 0070 data register -> c 0
0-6273 0132 a exchange b[w]
0-6274 0232 a exchange c[w]
0-6275 1410 decimal
0-6276 1314 0 -> s 11
0-6277 ----- 1020 return
0-6300 G7077 0432 0 -> c[w]
0-6301 0610 n exch c
0-6302 0077 if n/c go to 6017
> 0-6303 G0003 1760 hi i'm woodstock ; entry after power on reset
0-6304 0432 0 -> c[w]
0-6305 0410 m exch c ; clear m
0-6306 0432 0 -> c[w]
0-6307 0610 n exch c ; clear n
0-6310 0110 clear s
0-6311 0420 binary
0-6312 0464 delayed rom 04
0-6313 1165 jsb 2235 ; 0-2235 read reg 46
0-6314 0272 c -> a[w]
0-6315 1701 jsb 6360 ; load constant x34934284xxxxx to c
0-6316 1626 a - c -> a[m]
0-6317 1526 if a[m] # 0
0-6320 0334 then go to 6334 ; RAM Error
0-6321 1474 p = 0 ; RAM OK
0-6322 0402 0 -> c[p]
0-6323 1651 jsb 6352 ; load ram_addr 32 0x20
0-6324 1650 c -> data register 14
0-6325 0416 0 -> c[x]
0-6326 1074 p = 1
0-6327 0130 load constant 1
0-6330 1160 c -> addr
0-6331 1260 clear data registers ; Clear register 0x10-0x1F
0-6332 0064 delayed rom 00
0-6333 0307 if n/c go to 0061
0-6334 0432 0 -> c[w] ; RAM error after power up
0-6335 1074 p = 1
0-6336 0330 load constant 3 ; load data adress 0x30
0-6337 1074 p = 1
0-6340 0264 delayed rom 02
0-6341 1751 jsb 1372 ; ->1112 clear data registers 0x2F-0x00
0-6342 0432 0 -> c[w]
0-6343 1701 jsb 6360 ; load constant x34934284xxxxx
0-6344 0574 p = 2
0-6345 0230 load constant 2 ; default show 2 decimals
0-6346 1651 jsb 6352 ; set data address base 0x20-2F here set to 2F
0-6347 1650 c -> data register 14 ; write 03493428400200 to reg 46
0-6350 0264 delayed rom 02
0-6351 1763 if n/c go to 1374
0-6352 0232 a exchange c[w] ; set ram_addr 0x2x for access registers 32-47 x=a[0]
0-6353 1074 p = 1
```

b.) Main Loop



```
0-0137      0764 delayed rom 07
0-0140      1701 jsb 3760
0-0141      0623 if n/c go to 0144
0-0142      0464 delayed rom 04
0-0143      0001 jsb 2000
0-0144      0264 delayed rom 02
0-0145      1745 jsb 1371
0-0146      1760 hi i'm woodstock      ; entry after power up and after button processed
0-0147      0310 display off
0-0150      0210 display toggle      ; display on
> 0-0151      0004 1 -> s 0      ; main idle loop in RUN and PRGM mode
0-0152      0114 0 -> s 1
0-0153      0314 0 -> s 3      ; check RUN/PRGM switch 0=PRGM 1=RUN mode
0-0154      0334 if 0 = s 3
0-0155      0163 then go to 0163      ; program switch set to PRGM
0-0156      1334 if 0 = s 11      ; already RUN mode ?
0-0157      0165 then go to 0165      ; yes
0-0160      1314 0 -> s 11      ; no, switch to RUN mode
0-0161      0372 b exchange c[w]
0-0162      0313 if n/c go to 0062
0-0163      1334 if 0 = s 11      ; already PRGM mode ?
0-0164      0265 then go to 0265      ; no, switch to PRGM mode
0-0165      0014 0 -> s 0
0-0166      0514 0 -> s 5      ; check battery low?
0-0167      0524 if 1 = s 5
0-0170      0173 then go to 0173      ; battery OK, skip blinking
0-0171      1765 jsb 0375      ; blink decimal, return if button pressed
0-0172      1765 jsb 0375      ; blink decimal, return if button pressed
0-0173      0314 0 -> s 3
0-0174      1320 pik keys?      ; button pressed ?
0-0175      0334 if 0 = s 3
0-0176      0151 then go to 0151      ; no
0-0177      0310 display off      ; yes, process button
0-0200      0372 b exchange c[w]      ; save c reg to b
0-0201      1135 jsb 0227      ; read PIK register
0-0202      1664 delayed rom 16
0-0203      1653 if n/c go to 7352
0-0204      0314 0 -> s 3
0-0205      1424 if 1 = s 12
0-0206      0212 then go to 0212
0-0207      1320 pik keys?
0-0210      0324 if 1 = s 3
0-0211      0224 then go to 0224
```

The main Loop cycles between address 0151-0176. It has three duties.

- 1.) Check whether the RUN/PRGM switch has changed, check S3 input while S0=1
- 2.) Check whether the Battery is low, S5 1=OK 0=Low
- 3.) Check whether there is a key in the PIK keyboard buffer

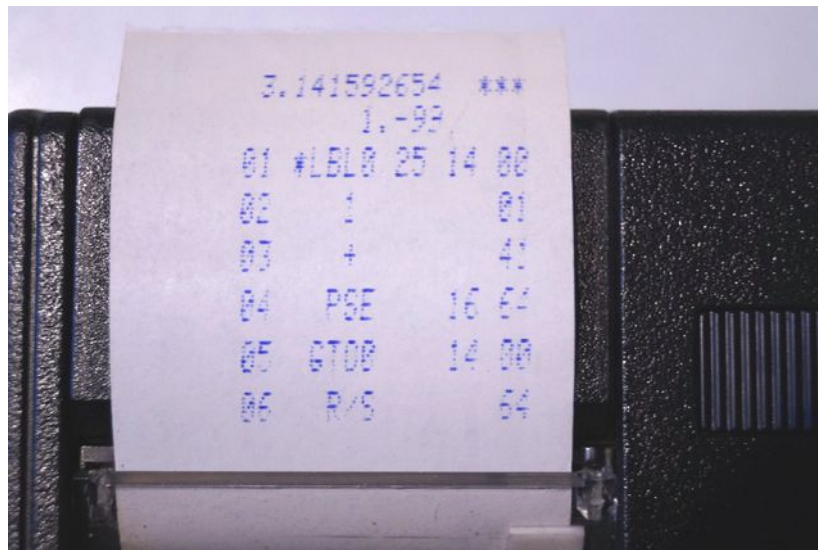
If the switch has changed to PRGM, execution jumps to 0265 and returns to main loop

If the switch has changed to RUN, execution jumps to 0062 and returns to main loop

If the battery is low jsb 0375 is called twice which lets the decimal dot blink.

If there is a key in the PIK keyboard buffer the program executes from 0177 and first instruction is to switch off the display, then read the key code at 0201 and analyze it and jump to a destination jump table to process the key.

c.) How the print instructions work.



The HP-19C can print numbers and words. There are two print instructions: print3 (1720) and print6 (1660) to perform the printing.

Both instructions are interpreted by the PIK chip. In the processor concept of the HP calculators of the 70th the instruction decoding is distributed over several chips. There is no single ALU (Arithmetic Logic Unit). Both the ACT and the PIK chip (and also RAM chips) have separate instruction decoders, which listen to the serial opcodes when ROM code is executed. Most instructions are decoded by the ACT. But some instructions are decoded by the PIK chip, where the ACT executes NOP (no operation) in this case.

print3

When print3 is executed, the PIK reads the c register (which is serially output by the ACT DATA line every instruction) and interprets it as up to 14 numerical digits, each digit as 4-bit code. Besides the numbers 0-9 there are 4 special characters - . + *, which are useful for printing numbers. Consecutive print3 instructions can be used to construct the print line. The digits are stored in the print buffer with up to 21 characters and output by the pik cr (1220) instruction which starts also the printer motor.

HP-19C digits 4-bit code

4-bit	0x0	0x1	0x2	0x3	0x4	0x5	0x6	0x7	0x8	0x9	0xA	0xB	0xC	0xD	0xE	0xF
char	0	1	2	3	4	5	6	7	8	9	Dot	-	+	*	SPC	F

Example: Print Pi with 9 decimals



print3 c=FFFFFFFFFEEDDD this adds 3 asterisks and two spaces from right to left into the print buffer
print3 c=FEE3A141592654 this adds 4 5 6 2 9 5 1 4 1 . 3 and two spaces to the print buffer

print3 c=FFFFFFFFFFFFEE this adds 3 spaces to the print buffer

total of 21 characters



The printer buffer is a FIFO , which outputs first digit to the right of the paper. The printer motor moves from right to left while printing.

print6

The print6 instruction is used to print alphanumeric characters. Each character is coded as 6-bit, allowing a total of 64 characters including Space and some special characters, like arrows for ENTER↑ and superscripts (for \sin^{-1} and \cos^{-1} and x^2) .

HP-19C characters 6-bit code

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	N	Y	'='	0	L	M	≠	1	G	"	>	2	O	H	≤	3
1	P	√	X	4	R	F	Z	5	S	?	x	6	T	→	↑	7
2	%	'2'	Σ	8	\$	x	<	9	A	\$	\$.	B	\$	/	-
3	C	\$	/	+	D	\$	↑	*	E	e	↓	SPC	I	i	x	#

As we can see, the PIK chip contains only a subset of the 256 characters which were provided in the later HP82240 Infrared printer. There are only capital letters, except two small letters e and i, which are used for printing e^x and π . (\$ are unknown characters, I don't know which characters are located with these codes in the PIK, because they were never used in the HP-19C ROM and I was unable to print them).

Example: execute Last X in NORM mode

print 6 FFFFFFFB118712 this adds LSTX (as X T S L) to the print buffer

print 3 FFFFFFFEEEEEEEE this adds 8 spaces to the print buffer

print3 and print 6 instructions can be mixed for filling the printer buffer with characters

FB118712 = 1111 1011 0001 0001 1000 0111 0001 0010 = 11 111011 000100 011000 011100 010010

111011 (0x3B=SPC) 000100 (0x04 =L) 011000 (0x18 = S) 011100 (0x1c = T) 010010 (0x12 = X)



Please note: the PIK contains the printer pixel matrix and because other calculators like the HP-97 had a different character set the PIK chip has to be different. Developing new chips just for some characters!

d.) Statusbits

The ACT status register contains 16-bit. Some of them are directly connected to input pins (s3,s5 s15), s0 is directly connected to an output pin, Others are free programmable for different purposes.

bit	Description	Function
s0	bank switch signal and s15 PIK keybuffer input switch, s3 status bit	ACT/22 output
s1	SST pressed, always reset in idle loop	
s2	set if switched to PRGM mode	
s3	RUN mode switch und other hardware signals multiplexed	
s4	set if f or g prefix	
s5	set if battery OK 0=if battery low	
s6	set if f prefix	
s7	prefix RCL STO GTO GSB	
s8	prefix RCL GTO LBL, Math error	
s9	set after Power Up if RAM OK	
s10	internal use reset after clear prefix	
s11	0=RUN mode 1=PRGM mode	
s12	used by number entry	
s13	set if any prefix s4,s6,s7,s8, reset by clearprefix and any keypress	
s14	intermediate bit set if GRD Mode	
s15	keypressed if s0=0 and print switch if s0=1	latched input

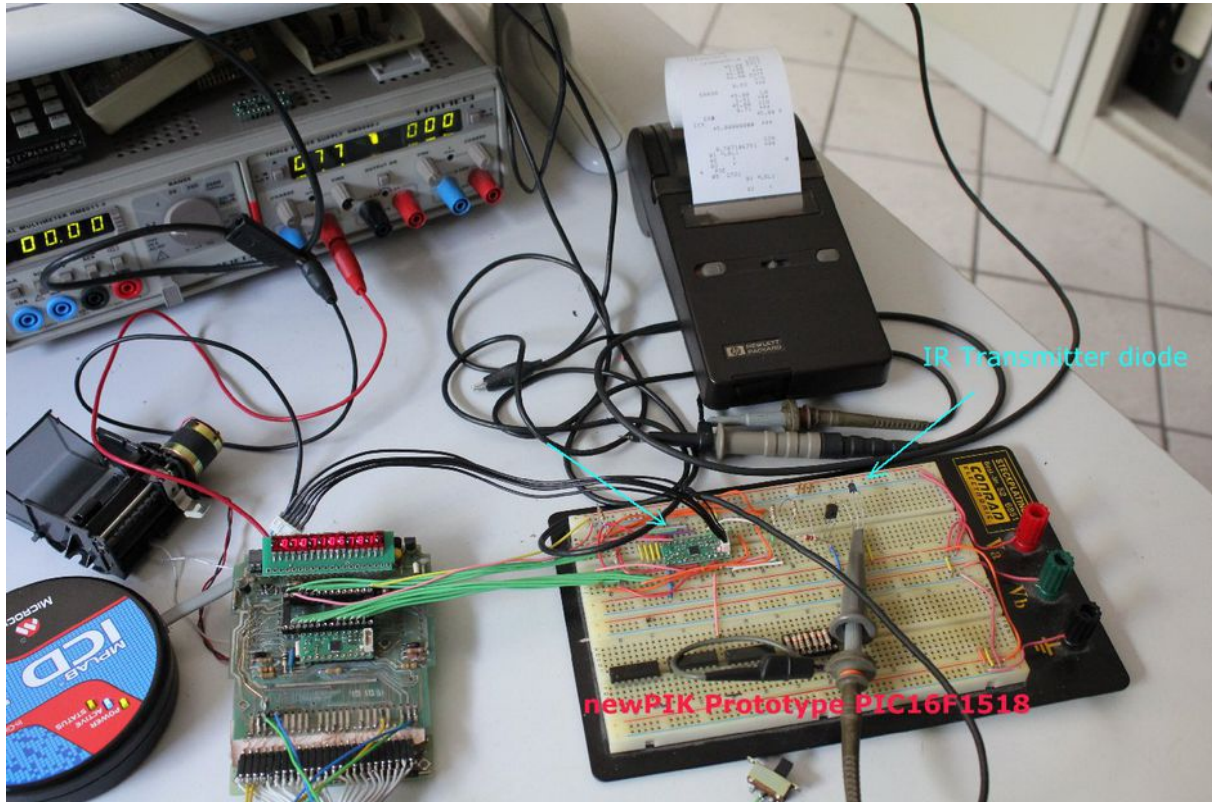
The actual status of trigonometric mode and display mode is not stored in the status register but in „Continuous Memory“ RAM register 46, which also contains the checkword for RAM consistency.

Show RAM 46 function in ACT Analyzer

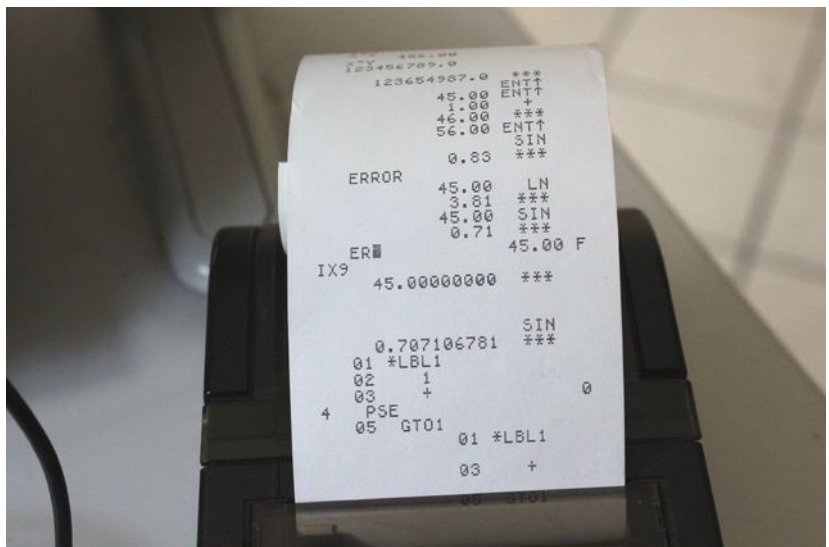
7.) The HP-19C ACT and PIK replacement

Beginning of 2020 I put considerable energy in a project to repair my totally corroded HP-19C to make it functional again. If this project would be finished, it could repair any HP-19C board, even if all ICs and components including the LED display are missing. Until now this project is unfinished, because I ran out of time and energy in summer 2020.

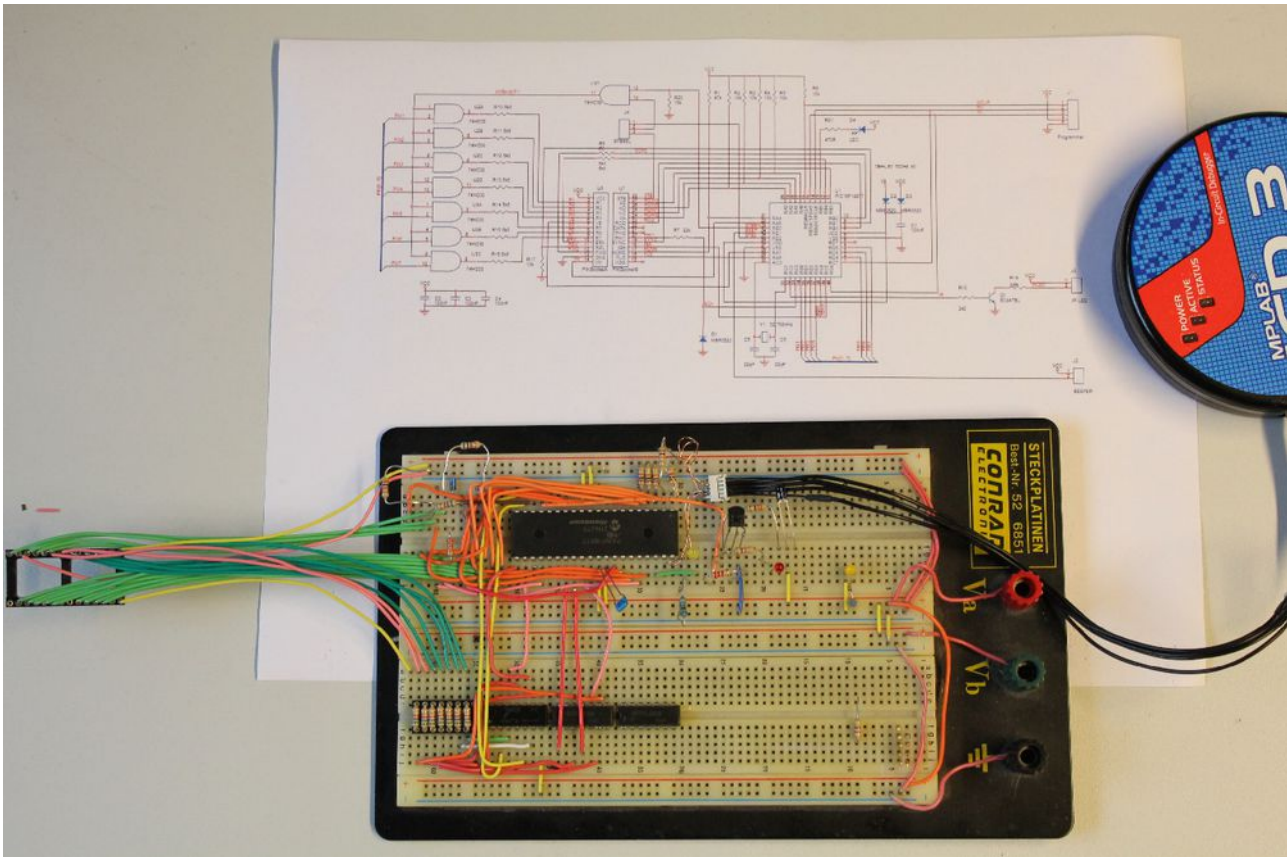
My first try with PIC16F1518 as PIK replacement was partially successful. The processor had not enough pins to output the printer pixels, but could print on IR printer.



The ACT of this prototype was programmed to emulate the complete HP-19C ROM code. Because there was no HP-19C LED display available I used a HP-25 display. I spared one digit by showing the decimal point not as separate digit. This was easy to achieve. The ACT communicated with the replacement PIK chip to read the keyboard buffer and to send print commands. The print commands were then output as Infrared signals to an HP-82240 printer, instead of driving the original printhead. I could achieve the complete HP-19C behaviour. This was the first time a HP19C printed to an HP82240 printer.



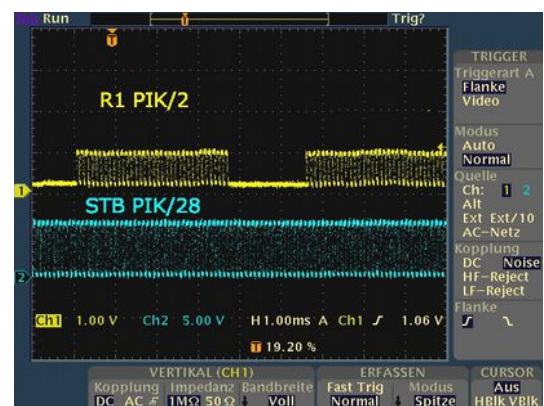
My second try with PIC16F18877 as PIK replacement was more successful. I used a PDIP chip package as seen below for the prototype, it is also available as very small VQFN package which could be easily placed on a PCB for replacing the 40-pin PIK chip.



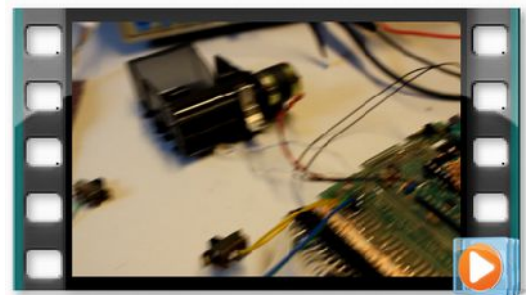
This second prototype board was able to print on paper, but the software is not yet finished.

For test purposes and not to ruin a valuable print head, I did not use the printer to control the printing output. The original printhead signals were generated by the PIK and checked by oscilloscope.

This screenshot shows the printhead pixel R1 (PIK Pin 2), gated by the STB signal (PIK Pin 28), which controls the print intensity. The STB signal is a 10 kHz PWM signal with variable duty cycle, which is generated by the network circuit on the printer PCB.



There is also a movie in the HP Museum forum of the printer motor, which shows the printer motor controlled by the prototype board.



Appendix A

a.) LED Display 21-pin connector

Pin	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	a	f	b	c	d	dp	e	g	3	2	4	1	5	12	6	11	7	10	9	8	13

1-13 = digits left to right common cathode

a-g, dp = 7 segments and decimal point anode

b.) Keyboard Connector 25-pin

Pin	1	2	3	4	5	6	7	8	9	10	11	12
	S1c	S2c	S2b	n.c.	Col5	S2a	Row6	Row 0	Row 1	n.c.	Row2	Col 1

13	14	15	16	17	18	19	20	21	22	23	24	25
Col 2	S1e	Col 4	n.c.	Col 3	Col 6	Col 7	Col 8	S1d	S1d	S1c	S1b	S1a

S1 = Switch 1 OFF/PRGM/RUN Three pins S1a, S1b, S1c

S2 = Switch 2 MAN/TRACE/NORM Three pins S2a S2n S2c

Col = 8 keyboard columns 1-8

Row = 4 keyboard rows 0,1,2,6

c.) Keyboard Matrix

31 buttons 4 Rows 8 Columns

Key	XY	R	GSB	GTO	SST	f
Matrix	11	12	13	14	15	16
Code	0x21	0x22	0x24	0x11	0x12	0x14

Key	ENTER	CHS	EEX	CLX	g
Matrix	21	22	23	24	25
Code	0x61	0x64	0x01	0x02	0x04

Key	-	7	8	9	$\Sigma+$
Matrix	31	32	33	34	35
Code	0x03	0x06	0x07	0x08	0x05

Key	+	4	5	6	STO
Matrix	41	42	43	44	45
Code	0x63	0x66	0x67	0x68	0x65

Key	x	1	2	3	RCL
Matrix	51	52	53	54	55
Code	0x23	0x26	0x27	0x28	0x25

Key	/	0	.	R/S	PRX
Matrix	61	62	63	64	65
Code	0x62	0x16	0x17	0x18	0x15



Maxtrix Code by Row Column

Row	1	2	3	4	5	6	7	8
0	EEX	CLX	-	g	$\Sigma+$	7	8	9
1	GTO	SST		f	PRX	0	.	R/S
2	X \leftrightarrow Y	Roll	x	GSB	RCL	1	2	3
6	ENTER	/	+	CHS	STO	4	5	6

Example PRX has code 0x15, 0x13 not used

d.) PIK Printer Interface Keyboard Chip

PIK Chip 28-pol

Pin	Symbol	Description	HP-19C Schematic
1	VSS	6,4 Volt	VCC
2	R1	digital output 19C Printhead 1	N5/2
3	R2	digital output 19C Printhead 2	N5/3
4	R3	digital output 19C Printhead 3	N5/5
5	R4	digital output 19C Printhead 4	N5/4
6	VB	V+ Bat (via ON/OFF switch) for Motor Power	N2/21 N2/22 S1d
7	R5	digital output 19C Printhead 5	N5/9
8	R6	digital output 19C Printhead 6	N5/8
9	R7	digital output 19C Printhead 7	N5/10
10	BRK	digital output 19C Motor Stop	N5/1
11	REV	digital output 19C Move Motor Reverse	N5/7
12	FWD	digital output 19C Move Motor Forward	N4/3 Q11/B
13	GND	Signal Ground	GND
14	VM	Input from Motor Speed Comparator	N5/6
15	VGG	-12 Volt	VGG
16	FLG	digital output Flag	U1/4 S3 Flag
17	HOME	digital input, High if floating	N4/5 Home Switch
18	ISA	Display digits, Address and Opcode	U1/10
19	SYNC	Instruction Gate Signal, Cycle Sync	U1/20
20	Phi1	180 kHz Clock 1	U1/17
21	Phi2	180 kHz Clock 2	U1/16
22	DATA	bidirectional Data Line reading key buffer	U1/11
23	RCD	Reset Cathode Driver (Keyboard Scan)	U1/21 U3/18
24	KA	Keyboard Row 2	N2/11
25	KC	Keyboard Row 1	N2/9 U1/8
26	KD	Keyboard Row 6	N2/7
27	KE	Keyboard Row 0	N2/8
28	STB	Input Print Intensity Comparator Waveform	N4/5

e.) HP-19C/HP-29C Program Codes

	0	1	2	3	4	5	6	7
0	R/S	ENTER↑	CHS	EEX	CLX	f REG	f Σ	GSB i
1	0	1	2	3	4	5	6	7
2	H→HMS	INT	√	y ^x	sin	cos	tan	ln
3	HMS→H	FRAC	x ²	ABS	sin ⁻¹	cos ⁻¹	tan ⁻¹	e ^x
4	FIX 0	FIX 1	FIX 2	FIX 3	FIX 4	FIX 5	FIX 6	FIX 7
5	SCI 0	SCI 1	SCI 2	SCI 3	SCI 4	SCI 5	SCI 6	SCI 7
6	ENG 0	ENG 1	ENG 2	ENG 3	ENG 4	ENG 5	ENG 6	ENG 7
7	GSB 0	GSB 1	GSB 2	GSB 3	GSB 4	GSB 5	GSB 6	GSB 7
	8	9	A	B	C	D	E	F
0	GTO i	RCL i	STO i	STO - i	STO + i	STO x i	STO : i	RCL Σ+
1	8	9	.	-	+	x	:	PRX
2	log	P→R	Last X	x ≤ y	x > y	x ≠ y	x = y	PR STK
3	10 ^x	R→P	π	x < 0	x > 0	x ≠ 0	x = 0	PR SPC
4	FIX 8	FIX 9	x ↔ y	R↓	PR Σ	PR REG	Σ+	DEG
5	SCI 8	SCI 9	/x	s	PAUSE	(DEG)	f Σ-	RAD
6	ENG 8	ENG 9	%	1/x	DSZ	ISZ	RTN	GRD
7	GSB 8	GSB 9	(GSB A)	(GSB B)	(GSB C)	(GSB D)	(GSB E)	(GSB F)
	0	1	2	3	4	5	6	7
8	GTO 0	GTO 1	GTO 2	GTO 3	GTO 4	GTO 5	GTO 6	GTO 7
9	RCL 0	RCL 1	RCL 2	RCL 3	RCL 4	RCL 5	RCL 6	RCL 7
A	STO 0	STO 1	STO 2	STO 3	STO 4	STO 5	STO 6	STO 7
B	STO - 0	STO - 1	STO - 2	STO - 3	STO - 4	STO - 5	STO - 6	STO - 7
C	STO + 0	STO + 1	STO + 2	STO + 3	STO + 4	STO + 5	STO + 6	STO + 7
D	STO x 0	STO x 1	STO x 2	STO x 3	STO x 4	STO x 5	STO x 6	STO x 7
E	STO : 0	STO : 1	STO : 2	STO : 3	STO : 4	STO : 5	STO : 6	STO : 7
F	LBL 0	LBL 1	LBL 2	LBL 3	LBL 4	LBL 5	LBL 6	LBL 7
	8	9	A	B	C	D	E	F
8	GTO 8	GTO 9	(GTO A)	(GTO B)	(GTO C)	(GTO D)	(GTO E)	(GTO F)
9	RCL 8	RCL 9	RCL .0	RCL .1	RCL .2	RCL .3	RCL .4	RCL .5
A	STO 8	STO 9	STO .0	STO .1	STO .2	STO .3	STO .4	STO .5
B	STO - 8	STO - 9	STO - .0	STO - .1	STO - .2	STO - .3	STO - .4	STO - .5
C	STO + 8	STO + 9	STO + .0	STO + .1	STO + .2	STO + .3	STO + .4	STO + .5
D	STO x 8	STO x 9	STO x .0	STO x .1	STO x .2	STO x .3	STO x .4	STO x .5
E	STO : 8	STO : 9	STO : .0	STO : .1	STO : .2	STO : .3	STO : .4	STO : .5
F	LBL 8	LBL 9	(LBL A)	(LBL B)	(LBL C)	(LBL D)	(LBL E)	(LBL F)

Appendix B

Does any collector own seven HP-19C and one HP-10 ?



Allschwil Meeting

Bernhard Emese PANAMATIK (c) 2022

Notice: