Epson HX-20 Tips and Tricks

Martin Hepperle, November 2018 – January 2024

Contents

1. General

The HX-20 was, and still is, a handy, portable computer with built-in printer and cassette drive – some call it the first laptop.

The LCD screen shows a window of 4 lines of 20 characters each into a virtual screen which can (in theory) be as large as 255 by 255 characters. In addition to text it can also display graphics at its resolution of 120x32 pixels.

The cassette drive can be replaced by a small ROM box and you can add a larger RAM/ROM box to the left side of the computer and you can install one ROM-chip inside the computer.

Additional devices like a barcode reader, a flexible disk drive unit and a display controller were available in those days.

The operating system and an adapted Microsoft BASIC are stored in 32 KB of ROM, which also contains a Monitor program. Furthermore 16 KB of RAM are installed inside the computer. The BASIC also provides commands for graphics and for the RS-232C interface. It can also call routines in machine code. Programs and data files can be stored in RAM and are immediately available after switching the device on.

The serial RS-232C interface can be used to communicate with other computers or printers and modems. A second „high speed interface“ was intended to be used by disk drives and display controllers. It is not directly supported in BASIC, but can be used by programs in machine language.

The HX-20 computer was often used by sales forces, in surveying, agriculture and for mobile data acquisition or even by the military. For these applications additional peripherals have been constructed and can sometimes be found installed on these systems.

Because of the robust mechanical design the HX-20 is a long lasting computer – except for some aging problems of it electronics components.

2. Power Supply

2.1. Transformer Unit

The transformer unit for the HX-20 should never be used without the built-in battery. On the on hand side the battery acts as a buffer for actions with high power demands, for example printing or accessing the cassette drive. Peak currents can exceed 1 A. On the other hand the battery charging load reduces the voltage of the transformer to the required voltage of about 5 V.

The charging time of the original Ni-Cd cells (having about 1100 mAh) is roughly 8 hours. When new cells with a higher capacity of 2000 mAh are used, the charging time grows to 14 hours. In order to maximize battery life you should avoid overcharging the battery.

The original transformer unit is matched to the battery circuit of the HX-20. It supplies its nominal voltage of 6V at 600 mA only when it is loaded by charging the battery. The 5.5/2.1 mm barrel plug carries plus on the outer barrel and minus on the inner pin – most standard power supplies have the polarity reversed. The circuit in the HX-20 has a protection diode so that no damage can occur when the polarity is incorrect, but also no charging will take place.

You should always discharge the battery until the „CHARGE BATTERY !“ message appears, perform a full charge and then disconnect the power supply again.

Figure 1: The original power supply unit says “6 V” on the label.

Measurements show that the original power supply delivers about 9 V when unloaded, which results in an initial charging current of 250 mA. During charging the current drops rapidly down to 150 mA. When the battery voltage has reached its level of about 6V, the current has fallen to about 50 mA.

A modern regulated power supply of 6 V produced a low initial current of only 50 mA which quickly drops to 20 mA. After about two hours the current has become zero and the battery will never be fully charged.

Therefore, a replacement power supply must deliver about 9V and the charging current must be adjusted by inserting a suitable resistor into the cable. The average current should reach about 1/10 of the battery capacity (i.e. 200 mA for a 2000 mAh battery).

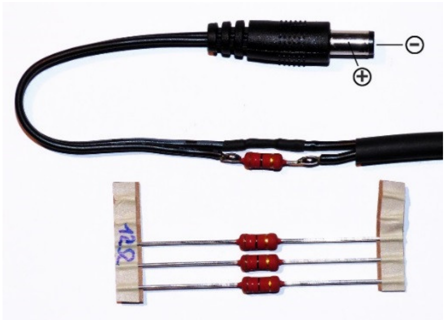


Figure 2: Using a modern, stabilized 9V/4.5W power supply with an inline 2 Watt resistor of 12 Ω yields an average charging current of 200 mA and a charging time of about 12-14 hours. The cable has to be cut anyway to reverse the polarity. Do not forget to slide the shrink tubing over the cable ends before soldering.

2.2. Replacing the Battery

- Ready-made battery packs with connectors can be found on eBay. I cannot say anything about their quality, but I would guess that they work fine. If you have the equipment, I recommend to charge and discharge the battery at least once using an external charger/discharger to determine their true capacity. Alternatively you can build your own battery pack from single NiCd cells. NiCd chemistry is preferable because the simple charging circuit (a resistor and a protection diode) in the HX-20 is designed for these cells. The cells must not be too large – there are small differences between so called „Sub-C“ cells and it is better to use smaller cells than to try to maximize the capacity. A capacity of 1000-1600 mAh is sufficient – you do not need 2500 mAh. For my last replacement I used shorter 4/5 SUB-C cells, which leave more room in the battery compartment for soldering the connectors but still have enough capacity.
- When working on the HX-20 you must avoid electrostatic charges. Use a grounded metallic or conducting foam work surface and ground yourself using a wrist strap.
- Place the computer with the keyboard facing down on a soft mat.
- Remove all seven screws on the bottom side and put aside.
- Turn the computer over, keeping the upper and lower shells together.
- Lift the upper shell at the rear end by about 5 cm. Use the front edge as a hinge. Now you can unlock the flexprint cable beside the battery pack by pulling the collar upwards. Then pull the ribbon cable carefully upwards, out of the connector.
- Now you can open the case completely, again using the front edge as a hinge. Careful with the two ribbon cables close to the front edge. You can lay both halves flat on our working surface, keeping the two ribbon cables in their connectors.
- Remove the screw in the metal plate over the battery pack and unhook the plate from the case.
- Place the new battery close to the computer – if you replace the battery within a minute or so, memory content will be maintained.
- Pull the old battery out of the cavity and unplug the connector.
- Plug the new battery in and place it into its cavity.
- Insert the metal plate and tighten the screw lightly. In case of a home-made battery pack: be sure that you do not create a short – the energy content of the battery pack can lead to a fire.
- Use your left hand to hold and fold the upper case back over the lower case, using the lower edge again as a hinge. Hold the rear open, insert the flexprint cable and close the lock by pushing the collar down, all with your right hand.

- When the case is completely closed, wiggle the lever under the microcassette drive (or ROM cartridge) slightly right/left to make sure it locks properly into its counterpart.
- Make sure that the blue cloth ribbon in the printer bay is properly placed and not caught between the case parts. Also check the proper routing of the printer paper.
- Check the proper placement of the panel with the serial connector cutouts in the rear wall.
- Before replacing the screws: test the system – if you obtain no display you might have to reattach the flexprint cable properly.
- If everything works: replace the screws and pull then hand tight.

2.3. Charging the Battery

The battery should only be recharged when the HX-20 tells you to do so. After charging, the charger should be unplugged to avoid overcharging. Figure 3 shows a time history of the charging current obtained with a 9 V power supply and a series resistor of 12 Ω. The charging was initiated after the HX-20 signaled "CHARGE BATTERY !" and a minimum of the current indicates the completion of the charge. A charging time of about 12 ±1 hours seems to be adequate for the 2000 mAh cells and this charger.

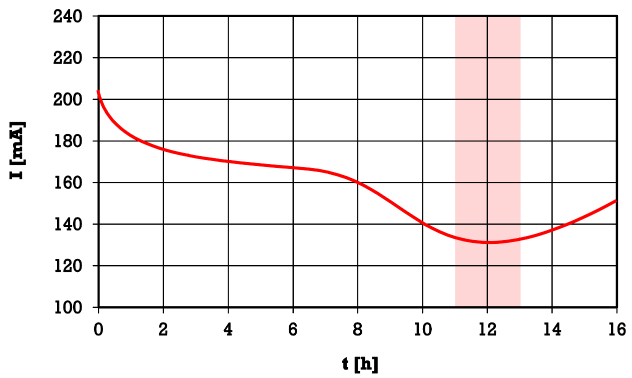


Figure 3: Charging current versus time for a NiCd battery pack having a nominal capacity of 2000 mAh.

3. Variations of the ROMs

The HX-20 cases differ slightly: earlier ones have an opening in the bottom cover where the auxiliary processor is installed – later ones do not have this additional opening. I encountered these systems:

- SN 011359, BASIC V1.0: has opening over slave processor
- SN 020734, BASIC V1.1: has opening over slave processor
- SN 040576, BASIC V1.1: has no opening over slave processor
- SN 042951, BASIC V1.1: has no opening over slave processor

The following was lifted from my document about adapting the Forth ROM to ROM versions.

ROM - Address	chk-8	crc-32	crc-16	Usage	Comments
0x8000_9FFF	54	33FBB1AB	336A	BASIC 2	same as Europe V1.0
0xA000_BFFF	5F	27D743ED	E1C5	BASIC 1	same as Europe V1.0
0xC000_DFFF	10	F5CC8868	A310	Menu, Monitor	same as Europe V1.0
0xE000_FFFF	F2	ED7482C6	E7F2	I/O	unique

Table 1: Japan ROMs V1.0.

ROM - Address	chk-8	crc-32	crc-16	Usage	Comments
0x8000_9FFF	54	33FBB1AB	336A	BASIC 2	same as Japan V1.0
0xA000_BFFF	5F	27D743ED	E1C5	BASIC 1	same as Japan V1.0
0xC000_DFFF	10	F5CC8868	A310	Menu, Monitor	same as Japan V1.0
0xE000_FFFF	20	A35DB3FC	A0B1	I/O	unique

Table 2: Europe ROMs V1.0.

ROM - Address	chk-8	crc-32	crc-16	Osage	Comments
0x8000_9FFF	C3	4DE0B4B6	E239	BASIC 2	same as Europe V1.1
0xA000_BFFF	22	10D6AE76	76E2	BASIC 1	same as Europe V1.1
0xC000_DFFF	7D	26C203A1	F3E9	Menu, Monitor	same as Europe V1.1
0xE000_FFFF	7E	101CB3E8	8ED7	I/O	unique

Table 3: Japan ROMs V1.1.

ROM - Address	chk-8	crc-32	crc-16	Usage	Comments
0x8000_9FFF	C3	4DE0B4B6	E239	BASIC 2	same as Japan V1.1
0xA000_BFFF	22	10D6AE76	76E2	BASIC 1	same as Japan V1.1
0xC000_DFFF	7D	26C203A1	F3E9	Menu, Monitor	same as Japan V1.1
0xE000_FFFF	F4	FD339AA5	2F07	I/O	unique

Table 4: Europe ROMs V1.1.

You can use the following program to detect the version of your ROM set:

```
10 C$="UNKNOWN"
20 D$="UNKNOWN"
30 B=PEEK(&HD760)
40 IF B=&H53 C$="JAPAN/EUROPE 1.0"
50 IF B=&H43 C$="JAPAN/EUROPE 1.1"
60 B=PEEK(&HE2EF)
70 IF B=&H3C D$="JAPAN 1.0"
80 IF B=&HE2 D$="JAPAN 1.1"
90 IF B=&H18 D$="EUROPE 1.0"
100 IF B=&H81 D$="EUROPE 1.1"
110 PRINT "C000-DFFF=";C$
120 PRINT "E000-FFFF=";D$
130 END
```

Listing 1: Basic program to identify the three ROM versions.

What I call JAPAN might better be called INTERNATIONAL. The true Japanese HC-20 have another ROM set for the Katakana keyboard and character display. For more details abut the European and International ROM sets, read the document about my modifications to the Forth ROM.

4. New Printer Paper

- You can use any non-thermal printer paper with a width of 57…58 mm. In order to fit the tight space you probably have to roll-your-own from a larger roll of paper. Just take a pencil and wind a few meters of paper around it, keeping its side edges neatly aligned, remove the pen and you are ready to go.

5. New Printer Ribbons

- In most cases the old ribbons are dry and produce only weak printout if any. Also the foam rollers are disintegrating after so many years. Therefore, they tend to block the motion of the endless ribbon. Luckily, even in 2018 new cassettes are still available, because they seem to be used in printers of some Point-Of-Sales systems.

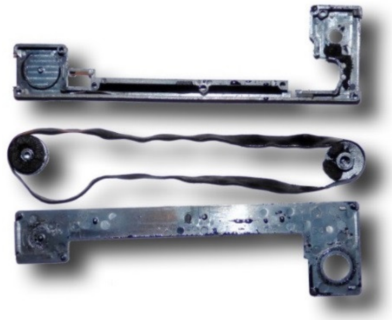


Figure 4: This ribbon cassette was taken apart to show the internal structure and the disintegrating foam wheels.

6. Internal RAM Boards

Some HX-20 come with an internal memory expansion. Originally Epson had not planned to allow for internal RAM extensions, but some tinkerers found out, that there was enough space inside the shell to add a board between keyboard and motherboard. A connector could be clamped onto the solder side pins of the external bus connector at the left edge of the case. This connection is the weak point of all boards – malfunctions are usually resulting from poor contact and I had to replace the flat spring connectors with strips from a "tuned precision socket" on the "mc" board to make it work again.

The issue April 1984 of the German computer magazine „mc" ("MicroComputer") presented a do-it yourself circuit layout for an 8 KB RAM expansion board. If no ROM modules were used, two of these „mc" boards could be added for the maximum of 16 KB RAM.

Similar boards were also produced by various manufacturers. These commercial boards usually came with 16 KB of RAM or ROM, which could be selected by a setup procedure with the monitor.

6.1. "mc" 8 KB RAM board

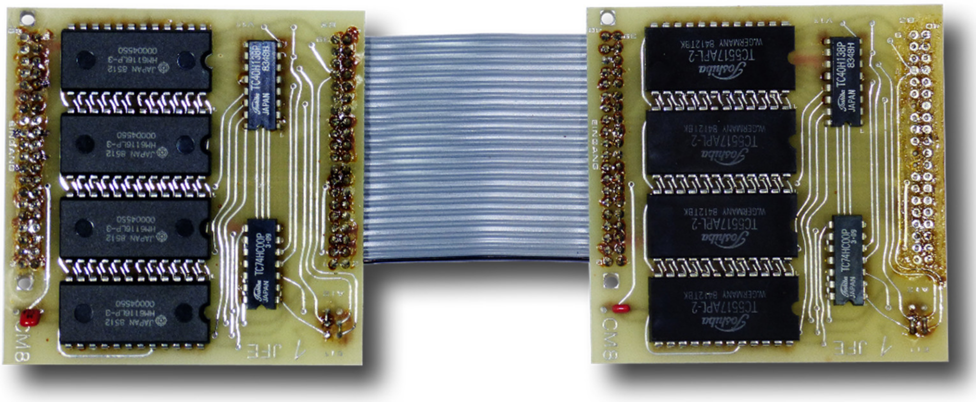


Figure 5: A set of two RAM boards as published in "mc" magazine. Both modules are identical and can be switched to a starting address by a solder bridge (a dip switch in the published design). Another switch can be used to deactivate each board if a ROM would be installed.

These boards require no special activation. One or two boards can be installed inside the HX-20, adding 8 to 16 KB of RAM. After installation, the usual full reset sequence is applied:

- Reset (press Reset button)
- Initialise (CTRL+SHIFT+@) / (CTRL+SHIFT+§)
- Start BASIC (2)
- Input `PRINT FRE(0)` (Return)

The result should be `29275`.

6.2. 16 KB RAM board Type 1

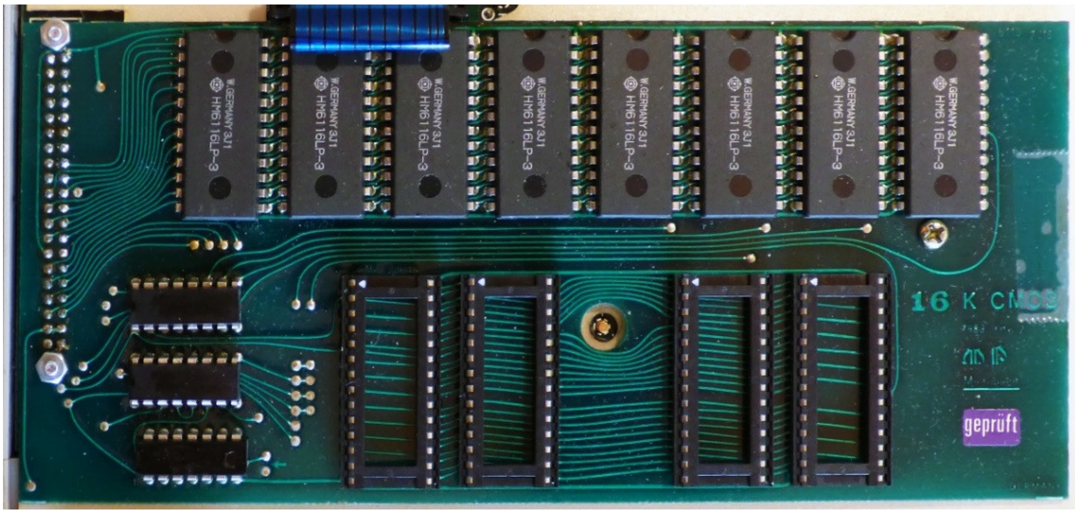


Figure 6: RAM board Type 1 with eight 2 KB RAM chips and four additional ROM sockets.

In order to make the full RAM capacity available the following procedure has to be applied:

- Reset — (press Reset button)
- Initialize — (CTRL+SHIFT+@) / (CTRL+SHIFT+§)
- Start Monitor — (1)
- Input `S7E` (Return) [setting $7E to $80 allows
- Input `80` (Return) accessing I/O address $3B below]
- Input `-` (Return)
- Input `S3B` (Return) [setting $3B (undocumented)
- Input `82` (Return) to $82 obviously enables RAM]
- Input `-` (Return)
- Input `B` (Return)
- Initialize — (CTRL+SHIFT+@) / (CTRL+SHIFT+§)
- Start BASIC — (2)
- Input `PRINT FRE(0)` (Return)

Again, the result should be `29275`.

6.3. 16 KB RAM board Type 2

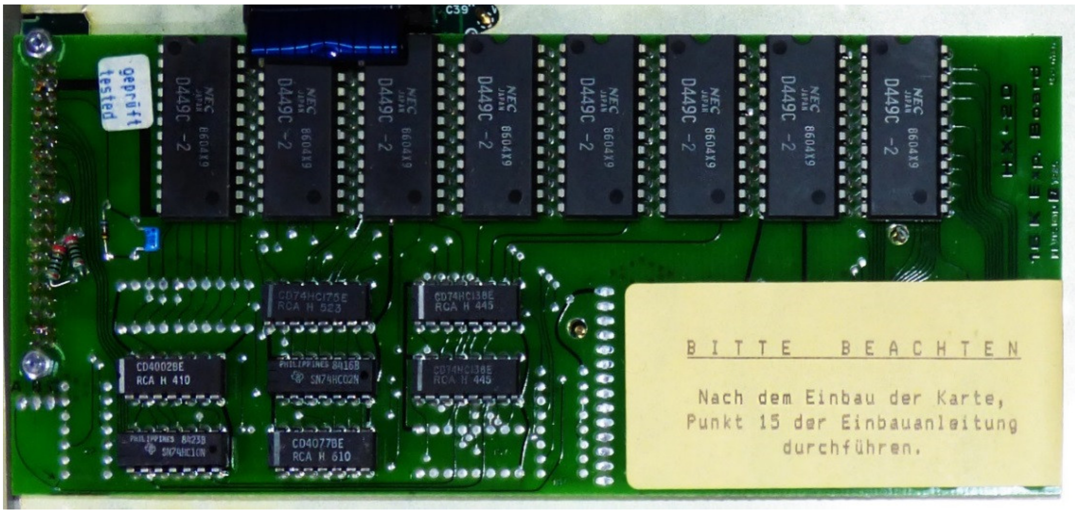


Figure 7: RAM board Type 2 produced by Steinwald with eight 2 KB RAM chips (the empty footprints under the sticker and the supporting TTL chips can also be populated with bank switched RAM).

The activation sequence for accessing the full 32 KB RAM for this board is:

- Reset — (press Reset button)
- Initialize — (CTRL+SHIFT+@) / (CTRL+SHIFT+§)
- Start Monitor — (1)
- Input `SFFF5` (Return) [setting this byte in high address range
- Input `0` (Return) enables 32 KB RAM]
- Input `-` (Return)
- Input `B` (Return)
- Initialize — (CTRL+SHIFT+@) / (CTRL+SHIFT+§)
- Start BASIC — (2)
- Input `PRINT FRE(0)` (Return)

As above, the result should be `29275`. The option ROM socket on the main board cannot be used.

The activation sequence for accessing 24 KB RAM plus the 8KB ROM socket on the mainboard is:

- Reset — (press Reset button)
- Initialize — (CTRL+SHIFT+@) / (CTRL+SHIFT+§)
- Start Monitor — (1)
- Input `SFFF5` (Return) [setting this byte in high address range
- Input `8` (Return) enables 24 KB RAM and 8KB ROM]
- Input `-` (Return)
- Input `B` (Return)
- Initialize — (CTRL+SHIFT+@) / (CTRL+SHIFT+§)
- Start BASIC — (2)
- Input `PRINT FRE(0)` (Return)

The result should be `21083`. The option ROM socket can be used e.g. for a FORTH ROM. The remaining 8 KB of RAM on the board are "wasted".

Note: you can also use `STAT ALL` to examine the memory configuration.

7. HX-20 for the Bundeswehr

The German Army used the HX-20 to determine firing tables for howitzers. Devices from old military stock appear regularly on eBay Germany, albeit at high asking prices around 100€ because these are offered by commercial dealers and gold diggers. Keep in mind that these devices have been modified and usually are not overhauled so that you will have to invest into a new battery as well as a replacement of the capacitors.

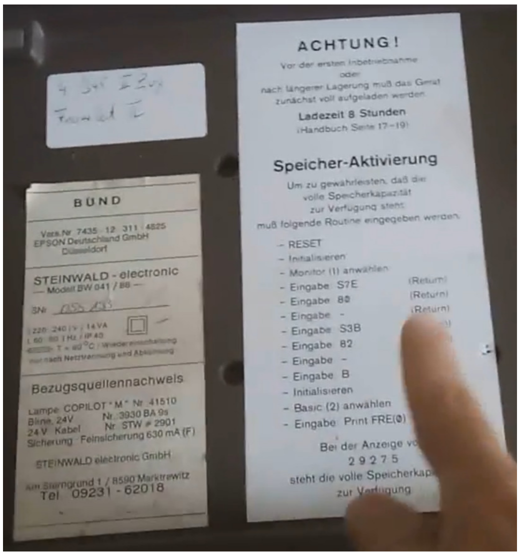


Figure 8: The instructions for activation.

These devices come in a modified suitcase with connectors for an external power supply and a reading lamp. They also have a memory expansion installed, which must be activated according to the instruction sheet.

The manufacturer of these modifications was:
Steinwald Electronic GmbH
Am Sterngrund 1
6590 Marktredwitz

Today the company name is:
STEINWALD Datentechnik GmbH
Oskar-Loew-Str. 12
95615 Marktredwitz

Figure 9: Some HX-20 come with a nice label template for tape operation.

8. Replacing the Capacitors

The HX-20 contains 14 electrolytic capacitors on its main board. These have exceeded their useful lifespan after more than 30 years. In most cases at least some are already leaking and the electrolyte can be found on the printed circuit board and in the gray discolored solder joints. When trying to run the HX-20 a weak or flickering LCD screen which cannot be adjusted to full contrast (all pixels dark) is a sign of bad capacitors. Then it is time to replace all of them. Besides a broken battery pack this seems to be the second most common problem with the HX-20.

The replacement is simple but tedious because the holes are relatively small and the old solder is difficult to remove. This is partially caused by the reaction with the electrolyte which seems to change the properties of the old solder. Despite some experience gained by refurbishing three HX-20, it usually takes me about two hours to replace all capacitors.

If available all capacitors should be of miniature size – you should revert to the standard size with a height greater than 7.5 mm only if you cannot source the smaller ones. The standard height capacitors must be mounted flat on the circuit board in order to fit the board into the case. In this case you have to bend the wires by 90 degrees. On the other hand this has the advantage that you can solder from both sides and better inspect the soldering joints. I found the miniature capacitors at Reichelt Elektronik in Germany, however not for all required capacities.

The following electrolytic capacitors are required:

C1, C2, C3, C4, C5, C6:	10 µF/16 V	4.3 mm Ø × 7.5 mm
C7, C8	33 µF/16 V	6.5 mm Ø × 7.5 mm
C9, C10, C11, C12	47 µF/16 V	6.5 mm Ø × 7.5 mm
C13	100 µF/6.3 V	6.5 mm Ø × 7.5 mm
C14	1 µF/16 V	6.5 mm Ø × 7.5 mm

A professional solder sucker of the pistol type is a good tool to remove the old solder, but in some cases additional mechanical rework might be necessary. Be careful not to damage the through-hole connections between upper and lower board layers.

If you discover electrolyte on the PCB or on the lower side of the old capacitor some cleaning of the board with water and alcohol should be performed to avoid corrosion.

Be sure that the new solder flows freely through the holes so that both sides of the PCB are wetted. Wiggling each wire slightly before removing the soldering iron helps the tin to flow through the narrow gap. To be sure that each solder joint is nice and without stresses I even reflow each joint after cutting the excess wires.

Figure 10: Some of the nasty culprits.

9. Replacing the Cassette Drive Belt

Most HX-20 are equipped with a micro cassette drive. It comes not as a surprise that the belt of this drive ages and finally breaks.

It can be replaced by a rubber belt with a square cross section of 0.8×0.8 mm to 1×1 mm and a circular inner diameter of about 50 mm. This corresponds to a width of approximately 80 mm when pressed into a flat shape ($2\times80 \approx \pi\times50$). The belts I used had a diameter of 49 mm and a nominal cross section of 1×1 mm. The cross section actually measured more like 1.2×1.2 mm which worked fine, but is the upper limit.

You need pointed tweezers, a small Phillips head screwdriver, a de-soldering tool and a soldering iron.

The parts include a few tiny M 1.4 screws, washers and spacers, which should be saved in a small container to avoid losing them. It may be wise to take some photographs or to make some sketches during the disassembly.

In order to replace the belt one has to partially dismantle the drive:

- Remove the drive box from the HX-20 by pushing the lever on the rear of the HX-20.
- Remove two screws from the bottom and take the bottom shell off.
- Remove the three 3 small screws holding the metal frame in the upper shell. Two screws above and below the connector and one on the opposite side.
- Unscrew the fourth screw with its small brass spacer at the upper edge of the PCB which fixes the PCB and the motor carrier in the upper shell.

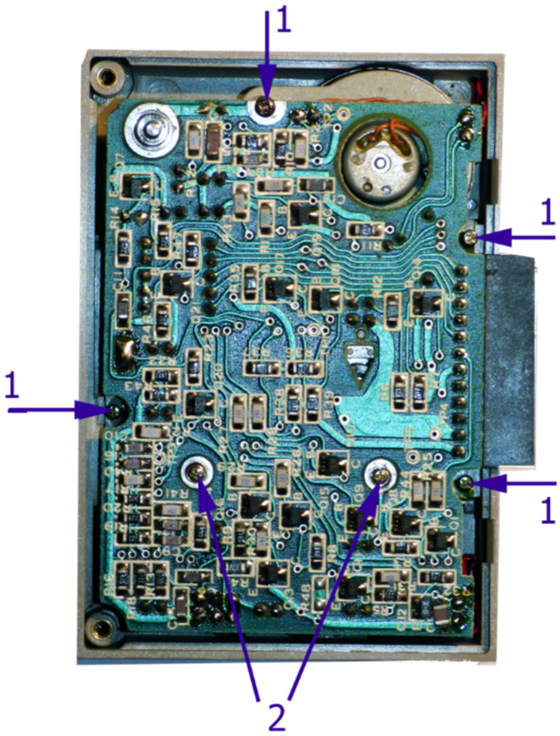


Figure 11: These screws have to be removed first:
1: Four screws to remove the drive assembly from the upper shell;
2: two screws to remove the PCB from the drive frame.

- Carefully remove the upper shell. Open the hatch and slide the shell off. There is a small internal sheet metal lever for pushing the hatch open. It can be rotated slightly around its vertical pivot axis to get out of the way. Do not use force, just wiggle the shell a bit and slide it off at an angle of about 45 degrees.
- Unscrew the two screws holding the PCB on the cast aluminum frame; take care of the two washers under the screw heads as well as the small stepped spacers under the PCB.
- Note the polarity and unsolder the two wires from the tachometer cap and both motor wires.
- Carefully unfold the PCB from the mechanical assembly. The remaining wires on one side serve as a “hinge”.
- Remove the metal bridge supporting the large drive wheel and the tension wheel (two screws).
- Unscrew the tachometer cap above the motor (2 screws plus 2 brass spacer tubes).
- Note: you might also want to inspect the three electrolytic capacitors, while you have the PCB on the table (C1: 47 µF/6.3 V, C2: 10 µF/16 V; C3: 2.2 µF/50 V). The tantalum capacitors seem to be less critical.

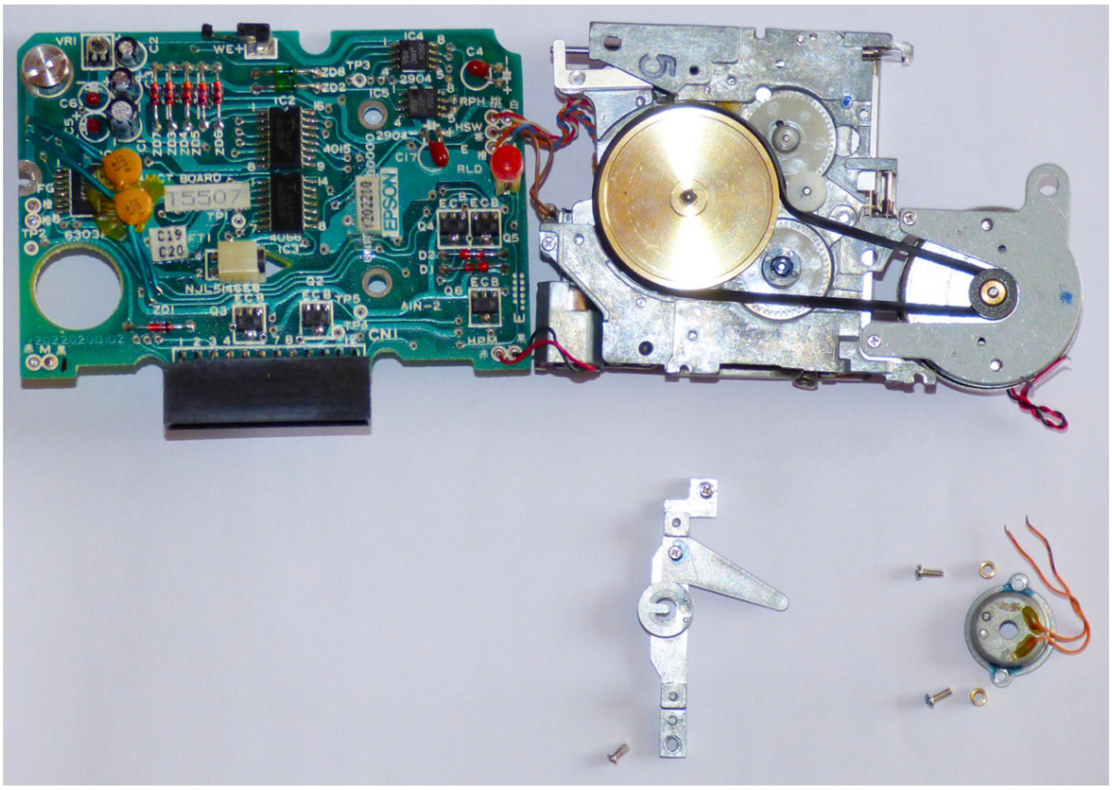


Figure 12: The PCB can be unfolded after unsoldering motor and tachometer cap wires and after removing the bar across the large drive wheel and the tachometer cap. The new belt has already been installed. In the upper left, you can also see the three electrolytic capacitors C1 to C3 on this board, which may also be replaced.

- Remove the old belt; note how the small white wheel applies tension to the belt.
- Install the new belt – it should fit the groves so that its cross section is angled at 45 degrees.
- Replace the mechanical parts.
- Turn the wheels manually to move the belt and make sure that is moves smoothly without rubbing against other parts.
- Replace all parts, except for the plastic shell covers.
- Solder the four wires back to where they belong.
- Plug the drive assembly into the HX-20 and make a test run (WIND, FILES, BREAK).
- If everything works, replace the two plastic shell parts.
- Make sure that the hatch can be opened with the lever; you may have to rotate the small internal sheet metal lever back so that it properly engages the hatch mechanism.

And that was it – phew!

10. Character Sets and Keyboards

The European ROM version of the HX-20 supports different character sets than the International or Japanese versions. For example the British pound sign is not present.

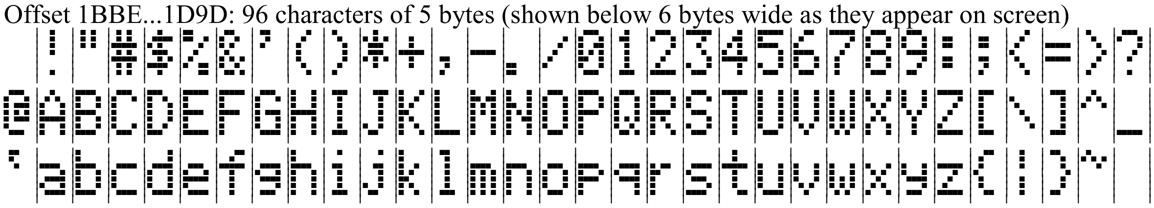
		country code							
		0	1	2	3	4	5	6	7
character code	35	#	#	#	#	#	#	#	#
	36	$	$	$	$	¤	$	$	¤
	64	@	@	@	É	É	§	à	É
	91	[	[	[	Æ	Ä	Ä	°	Æ
	92	\	\	\	Ø	Ö	Ö	ç	Ø
	93	]	]	]	Å	Å	Ü	§	Å
	94	^	^	^	Ü	Ü	^	^	Ü
	96	`	`	`	é	é	`	`	é
	123	{	{	{	æ	ä	ä	é	æ
	124	|	|	|	ø	ö	ö	ù	ø
	125	}	}	}	å	å	ü	è	å
	126	~	~	~	ü	ü	ß	¨	ü
country		SE	DE	FR	DK	SE	DE	FR	NO
		ASCII			national				

Figure 13: Character sets available in the European versions of the HX-20.

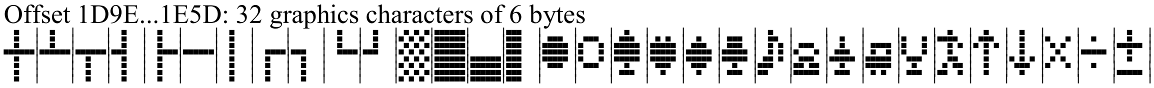
The country codes 0, 1 and, 2 have identical ASCII character sets, but different keyboard assignments.

These character bitmaps are stored in the last system ROM which is mapped into the memory range E000-FFFF. The following character bitmap patterns can be found at the given offsets into this ROM:

Offset 1BBE...1D9D: 96 characters of 5 bytes (shown below 6 bytes wide as they appear on screen)



Offset 1D9E...1E5D: 32 graphics characters of 6 bytes



Offset 1E5E...1ED0: 23 international characters of 5 bytes (shown below 6 bytes wide as they appear on screen)

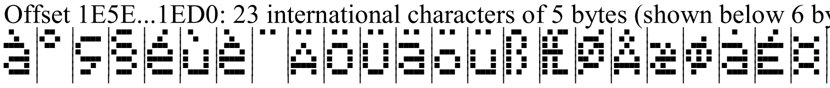


Figure 14: Character bitmaps in the system ROM of the HX-20.

Note that the given address ranges are for ROMs which show BASIC Version 1.1 on system start. The addresses in ROMs of Version 1.0 are shifted down by 8 bytes (the data starts at offset 1BB6). These addresses are valid for the European HX-20 models.

The character set can be switched by storing a byte between 0x10 and 0x17 (for country codes 0 to 7) at the address 0x7F and then executing the subroutine at 0xFF6A.

```
10 POKE &H7F,&H16
20 EXEC &HFF6A
```

11. Keyboards Types

So far I have encountered two different types of HX-20 keyboards. The first one uses individual mechanical key switches with flat spring contacts; the second type is built from two flexible membrane layers which carry conductive traces. Pressing a key deflects the upper membrane locally until it touches the lower layer. The first type is very robust and individual switches can be replaced or cleaned. The membrane-based keyboards seem to age less well and may develop problems depending on temperature or moisture. As the individual key mechanics are installed with melted plastic rivets, they cannot be removed without damaging them.

Figure 15: Top view of both keyboard types: the upper one is using membranes and assemblies of grouped switches, the lower one carries individually soldered in key switches.

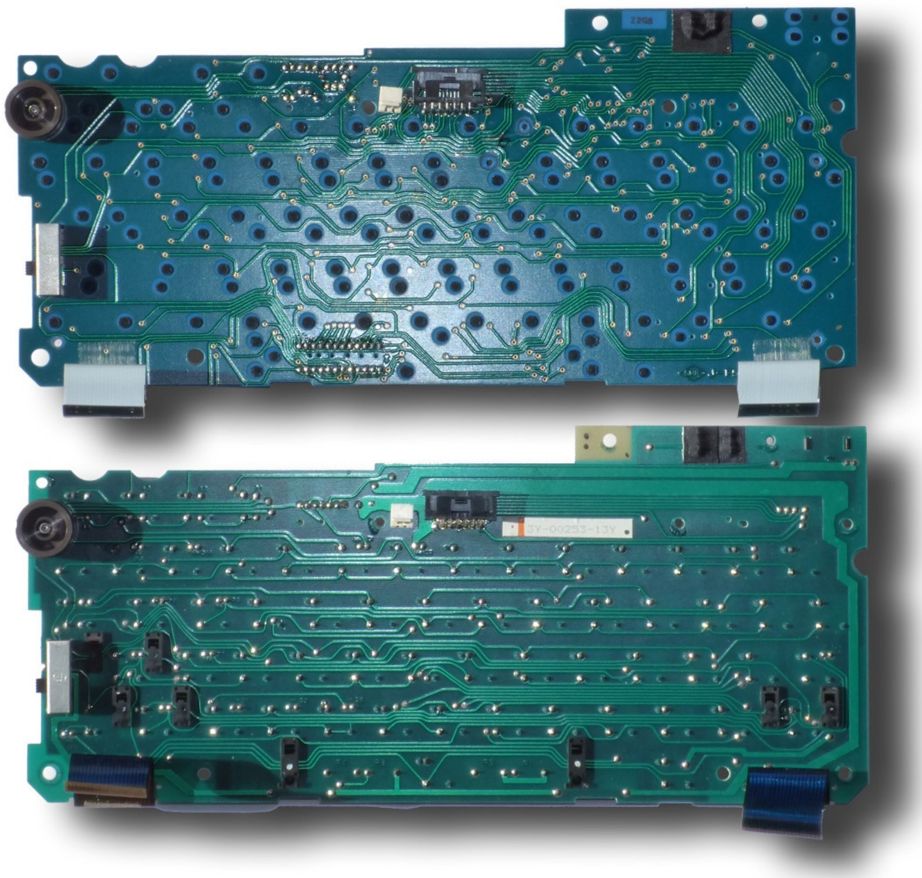


Figure 16: **Bottom view: the upper keyboard shows the black melted plastic rivets of the switch frames, the lower shows the soldered in key switches,**

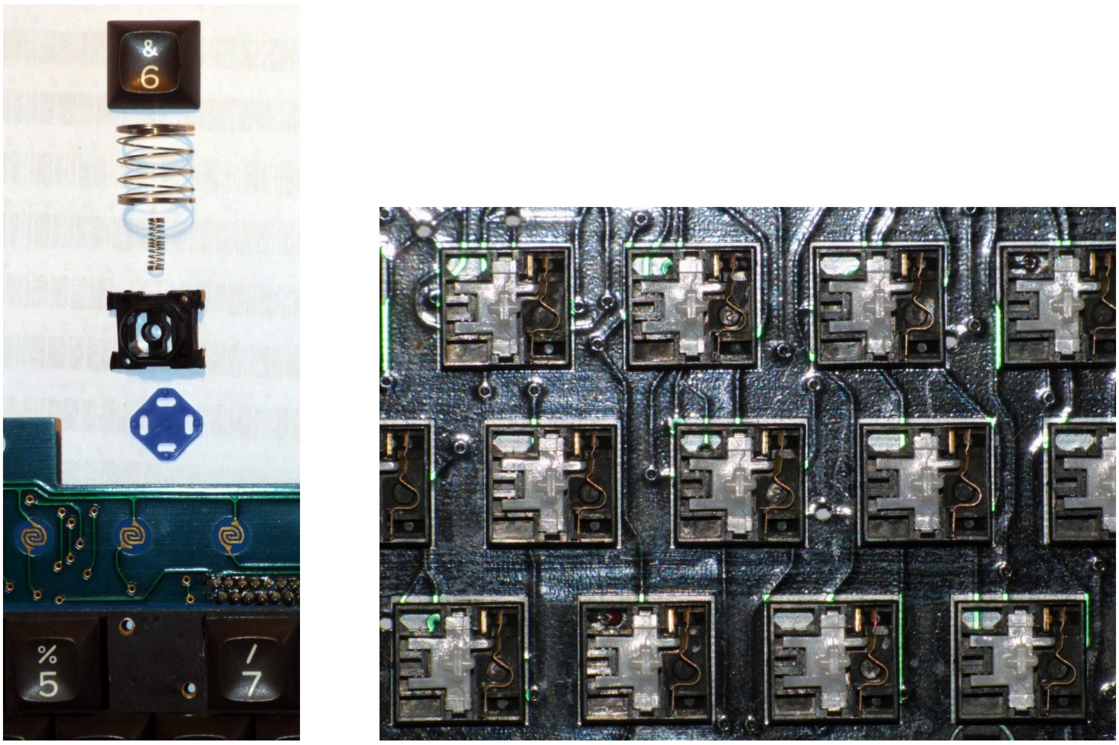


Figure 17: **Key ‘6’ assembly used on the membrane keyboard and close-up view of the mechanical counterparts.**

12. Loading BASIC Programs via RS-232C

The command

```
LOAD "COM0:"
```

can be used to load BASIC programs in text format from a second computer. If you have a Windows system, you can use the RealTerm or Teraterm software to send such files. Without handshaking an inter-character delay of about 10 ms is required to obtain a correct transmission at the default baud rate of 4800.

The sender should terminate the transfer by sending a last character of `CTRL-Z` (`0x1A`). Then the `LOAD` command terminates and returns to the command prompt. Otherwise one has to press the BREAK key on the HX-20 to terminate the transfer.

13. Controlling External Devices

The serial interfaces can be used to control any device with a serial interface. If only a simple on/off switching function is required, one can also use the “Remote” output of the HX-20. This connection is intended to control the motor of an external cassette recorder/player. As the schematic shows, it is completely decoupled from the HX-20 electronics by a relay and thus safe to use for external circuits.

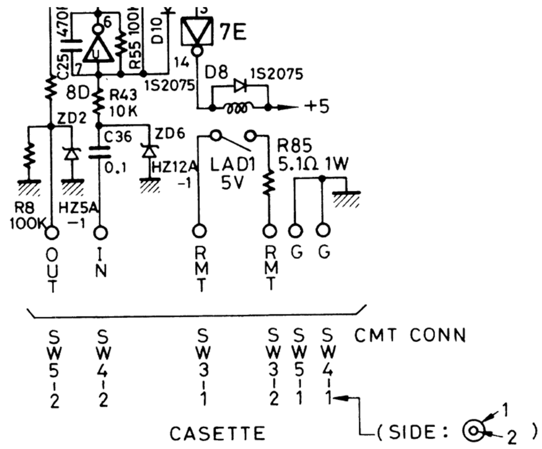


Figure 18: The HX-20 contains a relay to control an external cassette recorder via the REMOTE connector. It can be controlled by the MOTOR command.

The exact specification of this relay is unknown but the schematic shows a voltage of 5 V and a 5.1 Ω / 1 W current limiter resistor. Thus, the current drawn by the external device should never exceed 200 mA – I recommend keeping it below 50 mA at 5 V.

A 2.5 mm mono plug with a small diameter handle is needed for the connection. The small diameter is required for inserting the plug far enough into the HX-20. As I could only find 2.5 mm plugs with a too large diameter of the handle, I soldered the wires and then filled its body with epoxy resin. Finally I used a lathe to turn the diameter of the plastic handle partially down to the required diameter. Alternatively one could also use some silicone rubber or epoxy putty to create a suitable handle.

14. Some Useful Subroutines

14.1. User Defined Characters

The following program fragment can be used to define characters which are assigned to the GRAPH+0 and following keys. It has to be executed only once after a cold start.

```
10 REM Define NCHARS Characters
20 NCHARS=1
30 ADDR=&H0A40
40 MEMSET ADDR+6*NCHARS
50 REM Again, as MEMSET cleared all variables
60 ADDR=&H0A40
70 NCHARS=1
80 LO=ADDR AND &H00FF
90 HI=(ADDR/256) AND &H00FF
100 POKE &H011E,HI
110 POKE &H011F,LO
120 REM NCHARS Character Bitmap(s) of 6 bytes each
130 DATA 92,98,2,98,92,0
140 RESTORE 130
150 FOR N=1 TO 6*NCHARS
160 READ B
170 POKE ADDR,B
180 ADDR=ADDR+1
190 NEXT N
200 STOP
```

14.2. Get the Time in Seconds

By converting the return value of the `TIME$` function we can determine the seconds into the day:

```
210 REM Current Time in Seconds
220 T$=TIME$
230 T#=3600.#*CDBL(VAL(MID$(T$,1,2)))
240 T#=T#+60.#*CDBL(VAL(MID$(T$,4,2)))
250 T#=T#+CDBL(VAL(MID$(T$,7,2)))
260 RETURN
```

The current time is also maintained in the even memory locations between `0x0040` and `0x0044`. It can be read, converted and displayed by the following code fragment:

```
1000 REM --- TIME ---
1010 T%=0
1020 POKE &H007E,PEEK(&H007E) OR 128
1030 S%=PEEK(&H0040)
1040 M%=PEEK(&H0042)
1050 H%=PEEK(&H0044)
1060 S%=INT((S% AND &F0)/16)*10+(S% AND &H0F)
1070 M%=INT((M% AND &F0)/16)*10+(M% AND &H0F)
1080 H%=INT((H% AND &F0)/16)*10+(H% AND &H0F)
1090 IF S%=T% THEN 1030
1100 IF S%>59 THEN 1030
1110 PRINT USING "##:##:##";H%,M%,S%
1120 PRINT CHR$(&H1E);
1130 T%=S%
1040 T# = 3600.#*H% + 60.#*M% + CDBL(S%)
1150 GOTO 1030
```

Notes:

- Line 1020 enables access to the low memory region.

- Line 1090 waits to update the display every second.
- Line 1100 catches a problem: the seconds value may be larger than 59, probably when the PEEK in line 1030 occurs just when the clock is updated.
- Line 1120 moves the cursor back to overwrite the time output line.

14.3. Functions to obtain Low and High Byte of an Integer

```
230 DEF FNLO$(X%)=CHR$(X% AND &HFF)
240 DEF FNHI$(X%)=CHR$((X% AND &HFF00)/256)
```

14.4. Decoding a String with a Hexadecimal Number

This is a rather trivial application, but it is easily overlooked that the `VAL` function can do more than parse decimal numbers.

```
230 HX$=”0A40”
240 H%=VAL(“&H”+HX$)
```

15. Some Benchmark Results

The following table lists some execution times for the infamous BYTE Benchmark “Eratosthenes Primes” [3]. The times given for these roughly comparable systems are all for 10 iterations.

Computer	Year	CPU Type and Speed	Programming Language	Time
HX-20	1982	6301 @ 0.614 MHz	BASIC	4050 s
HX-20	1982	6301 @ 0.614 MHz	Assembler	17 s
HX-20	1982	6301 @ 0.614 MHz	Forth	229 s
TI-99/4	1981	TMS 9900 @ 3.0 MHz	TI-BASIC	3960 s
PET	1977	6502 @ 1.0 MHz	BASIC	3180 s
Apple][	1977	6502 @ 1.02 MHz	Applesoft BASIC	2806 s
HP-85	1980	Capricorn @ 625 kHz	BASIC	3084 s
HP-85	1980	Capricorn @ 625 kHz	Assembler	21 s
TRS-80/II	1977	Z-80 @ 1.77 MHz	MBASIC	2250 s
IBM PC	1981	8088 @ 4.77 MHz	BASICA	1990 s

Table 5: Some execution times for the BYTE benchmark.

We can clearly see that the HX-20 in BASIC mode is not exactly the fastest computer. In order to restore the honor of this machine I wrote an assembler version of the benchmark. As I had no experience with the 6800 family and the Hitachi 6301, the code is surely not optimized but the results should give a good estimate of what is possible.

```
                        ; -------------------------------------------------------
                        ; The infamous BYTE Benchmark Eratosthenes Sieve.
                        ; For the Epson HX/20 with Hitachi HS 6301 CPU.
                        ; -------------------------------------------------------
                        ; This assembly language program performs 10 loops
                        ; of the Sieve benchmark.
                        ; The number of primes is saved in variable "C" at
                        ; address 0x0ADA. The correct result is 1899 (0x076B).
                        ;
                        ; Enter the hex bytes starting at address 0xA40
                        ; using the Monitor.
                        ; Start with
                        ; S0A40
```

```
                     ; When the code up to address 0AD3 has been entered,
                     ; it can be executed from 0A40 until the PC reaches
                     ; 0ABE (Label STOP):
                     ; G0A40,0ABE
                     ;
                     ; Assembled from the ASM source with the a09 assembler:
                     ; a09 -oH01 sieve.asm -Lsieve.lst
                     ;
                     ; References:
                     ; BYTE Magazine, January 1983
                     ;
                     : Created 12/2018 Martin Hepperle
                     ; -----------------------------------------------------

                           OPT H01      ; Hitachi 6301

                           ORG $0A40
Addr Bytes
0A40 860A                  LDAA  #$0A    ; 10 times
0A42 B70AD4                STAA  REP     ; repeat count

                           ; set FLAG(0:8190)=1
0A45 CC0001          AGAIN LDD   #$0001   ; step size=1
0A48 FD0AD9                STD   P
0A4B 8601                  LDAA #$01      ; set flag
0A4D B70ADD                STAA F
                           ; starting address
0A50 CC0AE0                LDD   #FLAG    ; load address of FLAG, use as...
0A53 FD0ADE                STD   FPTR     ; ...starting address for FILL
0A56 BD0ABF                JSR   FILL     ; set *FPTR, *(FPTR+1), ... to F=1

                           ; preparation of loop
0A59 CC0000                LDD   #$0000   ; C=0
0A5C FD0AD5                STD   C        ;
0A5F CCFFFF                LDD   #$FFFF   ; I=-1 for starting loop at 0
0A62 FD0AD7                STD   I
0A65 8600                  LDAA #$00      ; clear flag
0A67 B70ADD                STAA F

                           ; I-loop from 0 to 8190
0A6A FC0AD7          NEXT  LDD   I
0A6D C30001                ADDD #$00001
0A70 FD0AD7                STD   I        ; I=I+1

                           ; compare I against 8191
0A73 18                    XGDX           ; D->X
0A74 8C1FFF                CPX   #$1FFF
0A77 273C                  BEQ   FINI     ; end of loop

                           ; FLAG[I] == 0?
0A79 CC0AE0                LDD   #FLAG    ; load address of FLAG
0A7C F30AD7                ADDD I         ; address of FLAG[I]
0A7F 18                    XGDX           ; D->X
0A80 A600                  LDAA $00,X     ; get value from FLAG[I]
0A82 27E6                  BEQ   NEXT     ; if already ZERO: continue I loop

0A84 FC0AD7                LDD   I        ; I
0A87 F30AD7                ADDD I         ; I+I
0A8A C30003                ADDD #$3       ; I+I+3
0A8D FD0AD9                STD   P        ; P=I+I+3

0A90 F30AD7                ADDD I         ; K=P+I
0A93 FD0ADB                STD   K

0A96 FC0AD5                LDD   C        ; get  C
0A99 C30001                ADDD #$00001   ; C=C+1
```

```
0A9C FD0AD5             STD  C          ; update count of primes

                        ; K > 8190?
0A9F FE0ADB             LDX  K
0AA2 8C1FFE             CPX  #$1FFE     ; 8190
0AA5 2EC3               BGT  NEXT       ; continue with loop

                        ; for J=K to 8190 step P
                        ; starting address
0AA7 CC0AE0             LDD  #FLAG      ; load address of FLAG[K]...
0AAA F30ADB             ADDD K          ; ...and use as...
0AAD FD0ADE             STD  FPTR       ; ...starting address for FILL

0AB0 BD0ABF             JSR FILL        ; set *(FPTR+K), *(FPTR+K+P), ...

0AB3 20B5               BRA NEXT
                        ; all done, repeat?
0AB5 B60AD4        FINI LDAA  REP       ; get repeat count
0AB8 4A                 DECA            ; decrement
0AB9 B70AD4             STAA  REP       ; store repeat count
0ABC 2687               BNE   AGAIN     ; not yet finished
0ABE 39            STOP RTS             ; finally

                        ; fill FLAG array from *BPTR with F step P
0ABF FE0ADE        FILL LDX  FPTR       ; address in BPTR = FLAG[J]

0AC2 8C2ADE        LOOP CPX  #FLGE      ; address of last byte in FLAG
0AC5 2E0C               BGT  DONE       ; beyond end of FLAG[]: leave loop
0AC7 B60ADD             LDAA F          ; flag value to set (byte)
0ACA A700               STAA $00,X      ; insert value into FLAG[J]
0ACC 18                 XGDX            ; X<->D
0ACD F30AD9             ADDD P          ; now D has X+P
0AD0 18                 XGDX            ; bring X+P back to X
0AD1 20EF               BRA  LOOP       ; again
0AD3 39            DONE RTS             ; done
                   ;    -------------------------
0AD4 00            REP  FCB $00
0AD5 0000          C    FDB  $0000      ; prime count, 1899d = 076Bh
0AD7 0000          I    FDB  $0000      ; loop count
0AD9 0000          P    FDB  $0000      ; step size
0ADB 0000          K    FDB  $0000      ; starting index
0ADD 00            F    FCB  $00        ; value to set
0ADE 0000          FPTR FDB  $0000      ; pointer to array element
                   ;    -------------------------
                   FLAG                 ; flag array
0AE0 00000000000000     FILL $00,8190   ; fill with zero
0AE7 00000000000000
     ...

2ADE 00            FLGE FCB $00         ; last byte in FLAG array
                        END
```

16. Writing Machine Language Routines

When I ran the BYTE benchmark "Eratosthenes Sieve" in BASIC, I was disappointed by the low performance. Experience from the HP-85 hinted that writing the code in machine language (using an assembler) could accelerate the program by a huge factor. Therefore, I started looking for ways to write and use assembler programs for the HX-20.

The BASIC Reference Manual contains a brief explanation how to call machine language subroutines with the `EXEC` and `USR` functions. It also explains the structure of BASIC variables so that these can be accessed by machine language programs.

This BASIC interface is rather limited, though: the `EXEC` function does not take any parameters but the `USR` function can take one parameter. Officially, the `USR` function always returns the same type as its parameter, i.e. if the parameter is an integer, the function return type must also be integer (but there is a way to change this by placing the result in the FPACC memory location and by adapting the type information in 0x0085-0x0086). If more than one parameter has to be transferred, these parameters could be copied to predefined global memory locations so that they can be accessed from BASIC as well as from the machine language program. Another option to handle multiple or mixed parameter types is to wrap the parameters into the bytes of a string and write the `USR` function to split this string parameter into its components. Finally for multiple numeric parameters an array could be used.

In Figure 19 I show the register set of the 6301 in comparison to the well-known 6800 and 6809. It can be seen that assembler code for the 6800 should be fairly easy to translate for the 6301. The 6809 has two additional 16-bit registers making a translation less straightforward.

For more information about programming the Hitachi 6301 one should consult the data sheet of the 6301 and books about the 6800 processor family. I could not find any specific book about the 6301, though.

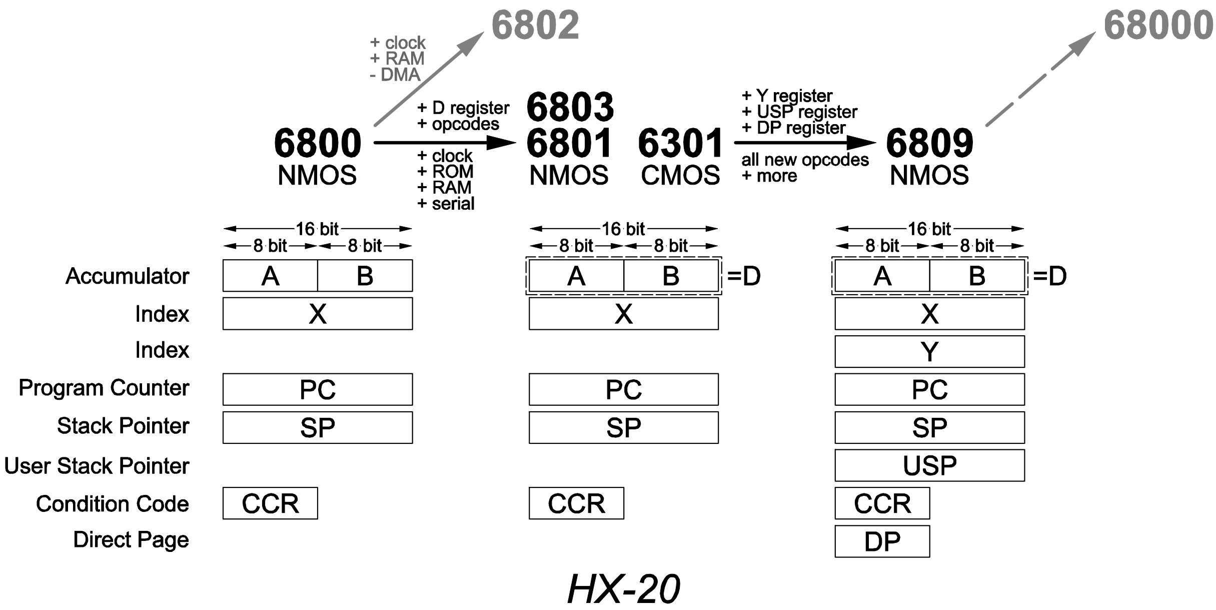


Figure 19: Registers of the 6301 and the related 6800 processor family.

An introduction into the 6301 CPU and its assembler language mnemonics is given in the book by Balkan [4]. It even contains a listing of an assembler written in BASIC and running on the HX-20 or other machines with Microsoft BASIC.

Unfortunately, the listing seems to have been typeset manually so that it contains about a dozen typos as well as one major bug. I used this assembler for my first exploratory steps (after fixing the typos and the bug and running it on a CP/M emulator with MBASIC). However, due to memory limitations of the 16 KB HX-20, this assembler is rather minimalistic.

Therefore, I searched again and found the A09 assembler which had also been extended to cover the 6301 opcodes. This assembler comes in plain “C” and I compiled and executed it on a Windows system. It can produce listings as well as binary and hexadecimal output. After fixing one bug in its 6301 opcode table it worked fine (by now, the fix should be integrated into the official release).

In order to load the assembled code into the HX-20 I wrote a small Python script which reads the listing file produced by A09 and transforms the code into a BASIC loader program, complete with `MEMSET`, `DATA` and the required `POKE` commands.

The transfer of this BASIC program to the HX-20 is accomplished by the RealTerm program at 4800 baud with an inter-character delay of 5…10 ms.

Thus, my process is

- Connect both machines with the proper RS-232C cable.
- On the PC:
  - assemble the code with `A09`,
  - convert the output into a BASIC loader program using `LST2BAS.py`,
  - set the communication parameters to 4800 baud, 8 bits, no parity, no handshaking and 1 stop bit,
- On the HX-20
  - execute `LOAD "COM0:(68N1E)"` to prepare for loading the program into the HX-20.
- On the PC:
  - use RealTerm to send the BASIC program to the HX-20,
  - wait until the program has been transferred.
- on the HX-20
  - inspect and execute the BASIC program,
  - this last step will actually write the machine code into memory.

After the machine code has been poked into memory, it stays there as long as no `MEMSET` command reduces the amount of reserved memory or another machine code program overwrites this memory. This means that the BASIC loader program has to be run only once. On the other hand, it does not hurt to run it again, if you want to be sure that the memory has not been altered. After loading, the machine code can also be saved to and read from the microcassette using the `SAVEM` respectively the `LOADM` commands. Unfortunately, it seems to be impossible to save and restore binary programs via the RS-232C interface.

If the machine code sequence in the `DATA` statements would become very large, one could modify the loader program to read the `DATA` from the RS-232C port or from tape. So far I wrote only small programs so that this was not necessary and I found it more convenient to keep the machine code together with the loader in a single program.

The Python script:

```
'''
This is a simple tool for converting the listing produced by the
A09 assembler into Epson HX-20 BASIC statements.

The resulting BASIC program loads the machine code into memory.
The code can then be executed by an EXEC statement or by
calling a USR function.

In the DATA statement starting addresses for a range of opcodes
or data are identifiable by a length of four characters.
All opcodes or data bytes are two characters long.
'''

import sys

# -----------------------------------------
```

```
def go ( s ):
   '''
   For Epson HX-20.
   Convert 6301 assembler listing file "s" into BASIC.
   '''

   # grab all (listing files are small)
   fIn = open(s);
   ss = fIn.readlines();
   fIn.close();

   nLines = len(ss);

   # values have to be adapted
   # RETURN is placed
   nStop  = 1070

   n = 10
   print (str(n)+' REM --- Epson HX-20      ---')
   n = n+10
   print (str(n)+' REM --- M. Hepperle 2018 ---')
   n = n+10
   print (str(n)+' REM --- adjust BASIC starting address')

   # skip MEMSET line
   n = n+10
   nMemSet = n

   n = n+10
   print (str(n)+' REM --- load the code bytes')
   n = n+10
   print (str(n)+' GOSUB 1010')
   n = n+10
   print (str(n)+' REM --- define the function')
   n = n+10
   nDefFn = n
   n = n+10
   print (str(n)+' REM --- application example')

   # -----
   n = n+10
   print (str(n)+' OPEN "O",#1,"COM0:(68N1D)"')
   n = n+10
   #print (str(n)+' PRINT USR1(CHR$(0)+CHR$(32)+CHR$(0)+CHR$(64)+"Hello World")')
   print (str(n)+' PRINT USR1("Hello World")')
   n = n+10
   print (str(n)+' CLOSE #1')
   # -----

   n = n+10
   print (str(n)+' REM --- if no parameters, then use:')
   n = n+10
   print (str(n)+' REM   EXEC &H0A40')
   n = n+10
   print (str(n)+' END')

   n = 1000
   print (str(n)+' REM --- Hex Code Loader  ---')

   n = n+10
   print (str(n)+' N%=0')

   n = n+10
   nLoop = n
   print (str(n)+' READ C$')

   n = n+10
   nReturn = n+50
   print (str(n)+' IF C$="DONE" THEN '+str(nReturn))

   n = n+10
   print (str(n)+' N%=N%+1 : IF N%=8 THEN PRINT "."; : N%=0')

   # new address, DATA MUST start with an address!
   n = n+10
```

```
print (str(n)+' C%=VAL("&H"+C$)')

# new address, DATA MUST start with an address!
n = n+10
print (str(n)+' IF LEN(C$)=4 THEN A%=C% : GOTO '+str(nLoop))

# new opcode
n = n+10
print (str(n)+' POKE A%,C% : A%=A%+1 : GOTO '+str(nLoop))

# nStop
n = n+10
if n != nReturn:
   print ('*** ERROR: increase nReturn by '+str(n-nReturn))
print (str(n)+' RETURN')


line=0;
address = 0

startAddress = 65536
endAddress = 0

sLine = ''

while line < nLines:
   l = ss[line].replace("\n","")

   # this is the End
   if l.startswith('SYMBOL TABLE'):
      break

   # continuation line has no blank in the first column
   if l[0:1] != ' ':
   #{
      # skip
      line = line+1
      continue
   #}

   addr = l[1:5].strip()

   if len(addr) == 4:
   #{
      try:
      #{
         addrDec = int(addr,16)

         if addrDec < startAddress:
         #{
            startAddress = addrDec
         #}

         if addrDec > endAddress:
         #{
            endAddress = addrDec
         #}

         if addrDec != address:
         #{
            # a step in addresses -
            # output new start address
            address = addrDec
            sLine = sLine + addr + ','
         #}

         opcodes = l[6:20].strip()
         i = 0

         while i < len(opcodes):
         #{
            sLine = sLine + opcodes[i:i+2] + ','
            i = i+2

            # update high water mark
```

```
            if address > endAddress:
            #{
               endAddress = address
            #}

            # next free address or start of BASIC for MEMSET
            address = address+1

            if len(sLine)>57:
            #{
               n = n+1
               print (str(n) + ' DATA ' + sLine[0:len(sLine)-1])
               sLine = ''
            #}
         #}
      #}
      except:
      #{
         addrDec = 0
      #}
   #}

   line = line+1
   if line > 50000:
   #{
      break
   #}

# flush DATA line
sLine = sLine + 'DONE'
n = n+1
print (str(n) + ' DATA ' + sLine[0:len(sLine)])


# insert MEMSET line above
print (str(nMemSet) + ' MEMSET &H' + hex(endAddress+1).upper()[2:])
print (str(nDefFn)+' DEFUSR1=&H'+hex(startAddress).upper()[2:])

# terminate transfer with ^Z
print ('\032')

if 1==1:
   print ('Comments:')
   print ('=========')
   print ('The binary code is loaded into RAM between &H' +
          hex(startAddress).upper()[2:]+' and &H' + hex(endAddress).upper()[2:]+'.')
   print ('Thus we need to use MEMSET to shift the start of the BASIC')
   print ('program and data area up:')
   print (' MEMSET &H' + hex(endAddress+1).upper()[2:])
   print ('')
   print ('If the code requires no parameters, you can execute it with')
   print (' EXEC &H' + hex(startAddress).upper()[2:])
   print ('')
   print ('If it takes one parameter, define it as a USR function:')
   print (' DEFUSR1=&H' + hex(startAddress).upper()[2:])
   print ('(Note that USR functions can have only one parameter.')
   print (' Multiple parameters can often be packed into a string or array)')
   print ('Call the function with its parameter and grab the return value:')
   print (' I%=USR1(...parameter...)')
   print ('')
   print ('The generic Hex Code loader at the end of the program reads DATA')
   print ('statements containing either four or two digit hexadecimal numbers.')
   print ('If the number has 4 digits it is interpreted as the "current address".')
   print ('Any following data bytes will be loaded starting at this address.')
   print ('If the number has two digits, it is a data byte which will be loaded')
   print ('to the "current address" and the address is incremented by one.')
   print ('This scheme allows loading data to arbitrary addresses, if desired.')
   print ('Reading the data stream is terminated by the data item DONE.')
   print ('')
   print ('If nothing changes, the data has to be read only once, so that')
   print ('you could add a test for e.g. the first and last bytes and skip loading.')
   print ('The assembler code should usually end with an RTS instruction (&H39).')

# ------------------------------------------
```

```
if __name__ == "__main__":
   if len(sys.argv)>1:
      basePath = "D:\\HP\\Epson HX-20\\ASM\\"
      basePath = './'
      fileName = sys.argv[1]
      go(basePath + fileName)
   else:
      print ('Usage: LST2BAS listing.lst')
```

16.1. Extending the Operating System

The BASIC Operating System of the HX-20 is astonishingly flexible and can be extended in various ways. One option is to add new devices. The core system already supports the devices

`KYBD:`	keyboard,
`SCRN:`	screen,
`LPT0:`	internal printer,
`CAS0:`	internal cassette (optional),
`CAS1:`	external cassette,
`PAC0:`	ROM cartridge (optional),
`COM0:`	RS232C,
`BRCD:`	barcode reader (optional),
“`A:`, `B:`, `C:`, `D:`	flexible disk units (optional).

The system allows up to 16 devices. Most devices of these can be accessed sequentially with standard BASIC statements like `OPEN`, `CLOSE`, `PRINT`, `INPUT`, `EOF`, `LOF` and so on.

For each device a device driver is installed in a device table, which is a list of addresses of “Device Control Blocks” (DCB). Each DCB has a prescribed structure and contains the name of the device as well as addresses to a set of required functions. It is possible to add devices by installing a device driver somewhere in RAM and adding the address of its DCB to the table. Before removing the driver, you should uninstall it, by zeroing the address entry in the device table.

The DCB has the following structure:

```
; Device Control Block
DCB:    FCB     "BUF0"          ; 4 character name
        FCB     $30             ; I/O modes: $01: read-only, $20: write-only,
$30: r/w
        FDB     OPENDEV         ; OPEN routine
        FDB     CLOSEDEV        ; CLOSE routine
        FDB     READDEV         ; READ routine
        FDB     WRITEDEV        ; WRITE routine
        FDB     EOFDEV          ; EOF routine
        FDB     LOFDEV          ; LOF routine
DEVBUF: FCB     $00,$00,$00,$00 ; for device purposes
COLPOS: FCB     $00             ; current column position (returned by BASIC
POS function)
MAXCOL: FCB     $00             ; max. column: $00: infinite
PRTTAB: FCB     $14             ; print zone width: step of “,” separated
PRINT output
LSTTAB: FCB     $00             ; last print zone on line
WIDTH:  FCB     $80             ; WIDTH support: $00: yes, $80: no
```

Following the name of the device it contains some flags and the addresses of 6 worker routines. These routines are called when the device is opened or closed, when bytes are read and/or written to the device and when the state of the device is inquired. I/O is performed on a sequential byte-by-byte basis, so this approach is not the fastest way to read or write large amounts of data. But all devices can be used easily with the standard I/O functions of BASIC.

The following example implements a simple device which provides a small ring buffer of 64 bytes. You can write data to the buffer and later read it back. It is rather useless, but serves as an example of a new device. It is installed with a small BASIC loader program and thus becomes available for all BASIC LOGINs. I decided to place it just below BASIC into RAM starting at address $0A40. This was the most convenient option for me.

To generate such a driver you

- write the assembler code, starting with the DCB and implementing the required functions,
- assemble the code with a suitable assembler (I use a09),
- translate the binary bytes into BASIC DATA statements and append it to the BASIC loader program (I use a python script to read the listing produced by a09),
- run the BASIC loader program, which
    - moves the starting point of BASIC up to leave room for the new device code,
    - loads the DCB and the code into the free space,
    - installs the address of the DCB in the device table.

After the driver has been installed, it can be used until it is removed from the device table by replacing the address of its DCB in the device table with null bytes. This removal is also implemented in the example BASIC program.

When the driver has been loaded once, it would also be possible to SAVEM it to a disk or tape file. Later, a BASIC program would only need the correct MEMSET and a LOADM command would replace the slow HEX loader. The MEMSET command is important to keep the allocated space from being overwritten by BASIC (there are also other but more complex ways to reserve space for such a driver).

```
; a09 device.asm -ldevice.lst
; python LST2BAS.py device.lst > device.bas

        ; HX-20: Hitachi 6301
        OPT H01
        OPT NCL

; insert below BASIC into the address range $0A40...$0AF7
        ORG     $0A40

;
; A device driver skeleton for the Epson HX-20
;
; Implements a simple device "BUF0:" which stores
; bytes written to it in a ring buffer.
; Reading from the device returns the bytes written until
; the buffer is empty.
; The LOF() function returns the amount of data currently in the buffer.
; The EOF() function returns 0 if there is something in the buffer,
;                            -1 otherwise.
;
; Example
;
; 10 REM --- Epson HX-20      ---
; 20 REM --- M. Hepperle 2024 ---
; 30 REM --- adjust BASIC starting address
; 40 MEMSET &HAF8;
```

```
; 50 REM --- load the device "BUF0"
; 60 GOSUB 350
; 70 REM --- application example
; 80 OPEN "O",#1,"BUF0:"
; 90 PRINT #1,"123";
; 100 PRINT "POS(1)=";POS(1)
; 110 PRINT #1,"ABC"
; 120 PRINT #1,"abc";
; 130 PRINT "POS(1)=";POS(1)
; 140 CLOSE #1
; 150 ON ERROR GOTO 240
; 160 OPEN "I",#1,"BUF0:"
; 170 PRINT "Buffer size=";LOF(1)
; 180 FOR I%=1 TO 100
; 190  C$=INPUT$(1,#1)
; 200  IF ASC(C$)=13 THEN C$="CR"
; 210  IF ASC(C$)=10 THEN C$="LF"
; 220  PRINT "/";C$;
; 230 NEXT I%
; 240 CLOSE #1
; 250 PRINT"/"
; 260 PRINT "UNLINK BUF0:"
; 270 INPUT "Y/N";YN$
; 280 IF YN$<>"Y" THEN GOTO 330
; 290 IF A%=0 THEN GOTO 330
; 300 POKE A%,0
; 310 POKE A%+1,0
; 320 PRINT "BUF0: at";A%;"removed"
; 330 END
; 340 REM --- Hex Code Loader  ---
; 350 N%=0
; 360 READ C$
; 380 IF C$="DONE" THEN 430
; 390 N%=N%+1 : IF N%=8 THEN PRINT "."; : N%=0
; 400 C%=VAL("&H"+C$)
; 410 IF LEN(C$)=4 THEN A%=C% : GOTO 360
; 420 POKE A%,C% : A%=A%+1 : GOTO 360
; 430 PRINT
; 440 REM install device control block in DCB table
; 450 DCBTAB%=&H0657
; 460 FOR A%=DCBTAB% TO DCBTAB%+30 STEP 2
; 470  C%=PEEK(A%)*256+PEEK(A%+1)
; 480  IF C%=&HA40 THEN GOTO 540
; 490  IF C%=&H000 THEN GOTO 520
; 500 NEXT A%
; 510 IF A%>DCBTAB%+28 THEN GOTO 560 : REM ERROR
; 520 POKE A%,&H0A : REM HIGH
; 530 POKE A%+1,&H40 : REM LOW
; 540 PRINT "BUF0: at";A%;"added" : REM remember A% for later removal
; 550 RETURN
; 560 PRINT "Cannot install BUF0:"
; 570 STOP
; 580 DATA 0A40,42,55,46,30,30,0A,5E,0A,5F,0A,60,0A,7C,0A,A0,0A,AC,00
; 590 DATA 00,00,00,00,00,14,00,80,0A,B8,0A,B8,39,39,FE,0A,5A,BC,0A,5C
; 600 DATA 27,0F,A6,00,08,8C,0A,F8,26,03,CE,0A,B8,FF,0A,5A,39,86,FF,97
; 610 DATA F5,39,5F,D7,F5,FE,0A,5C,A7,00,08,8C,0A,F8,26,03,CE,0A,B8,FF
; 620 DATA 0A,5C,81,0D,27,08,81,0A,27,04,7C,0A,55,39,7F,0A,55,39,5F,FE
; 630 DATA 0A,5A,BC,0A,5C,27,01,39,5A,39,FC,0A,5C,B3,0A,5A,2A,03,C3,00
; 640 DATA 40,39,DONE
; 650 REM --- END

; EOFLG   EQU     $00F8         ; EOF flag (error in Epson manual)
EOFLG   EQU     $00F5           ; EOF flag (J. Wald and system ROM A000-BFFF)

; ----------------------------
; Device Control Block
DCB:    FCB     "BUF0"          ; 4 character name
```

```
        FCB     $30             ; I/O mode: $01: r, $20: w, $30: r/w
        FDB     OPENDEV         ; OPEN routine
        FDB     CLOSEDEV        ; CLOSE routine
        FDB     READDEV         ; READ routine
        FDB     WRITEDEV        ; WRITE routine
        FDB     EOFDEV          ; EOF routine
        FDB     LOFDEV          ; LOF routine
DEVBUF: FCB     $00,$00,$00,$00 ; for device purposes
COLPOS: FCB     $00             ; current column position see BASIC POS(#)
MAXCOL: FCB     $00             ; max. column: $00: infinite
PRTTAB: FCB     $14             ; print zone width: step of "," PRINT output
LSTTAB: FCB     $00             ; last print zone on line
WIDTH:  FCB     $80             ; WIDTH support: $00: yes, $80: no
; ------------------------------
; max. 64 bytes
READPT  FDB     BUFFER          ; initialize read and write addresses
WRITPT  FDB     BUFFER          ; initially buffer is empty

; ----------------------------------------------------------
; called by OPEN
; OPEN "I",#1,"BUF:"
; OPEN "O",#1,"BUF:"
OPENDEV
        ; no action
        RTS

; ----------------------------------------------------------
; called by CLOSE
; CLOSE #1
CLOSEDEV
        ; no action
        RTS

; ----------------------------------------------------------
; called e.g. by INPUT$
; C$=INPUT$(n,#1)
; read one byte from device
; return byte in (A) or set EOFLAG to $FF on EOF
READDEV
        LDX     READPT          ; get read address
        CPX     WRITPT          ; compare with write position
        BEQ     READ_EOF        ; buffer is empty

        LDAA    ,X             ; get byte from buffer
        INX                     ; increment pointer
        CPX     #BUFEND         ; get address
        BNE     READ_1          ; o.k.
        ; wrap
        LDX     #BUFFER         ; back to start
READ_1
        STX     READPT          ; for next read

        RTS

READ_EOF
        LDAA    #$FF            ; EOF: $FF
        STAA    EOFLG           ;

        RTS

; ----------------------------------------------------------
; called e.g. by PRINT#
; PRINT# 1,"ABC"
; write one byte to device
; (A) byte to write
WRITEDEV
        CLRB            ; not at EOF: $00
```

```
        STAB    EOFLG   ;

        LDX     WRITPT          ; get current write address
        STAA    ,X              ; store byte
        INX
        CPX     #BUFEND          ; get address
        BNE     WRITE_1

        ; buffer overflow: wrap
        LDX     #BUFFER          ; get start address

WRITE_1
        STX     WRITPT           ; for next write
        ; increment or reset POS
        CMPA    #$0D
        BEQ     ZERPOS
        CMPA    #$0A
        BEQ     ZERPOS
INCPOS  INC     COLPOS  ; increment column index
        RTS
ZERPOS  CLR     COLPOS  ; reset column index
        RTS

; ------------------------------------------------------------
; called e.g. by EOF(1)
EOFDEV
        CLRB                    ; not at EOF
        LDX     READPT          ; get read address
        CPX     WRITPT          ; compare with write position
        BEQ     EOF             ; buffer is empty
        RTS
EOF
        DECB                    ; return $FF EOF flag
        RTS

; ------------------------------------------------------------
; called e.g. by LOF(1)
; return # of bytes in buffer

; wrapping example/test case with 7 byte buffer
;  [.ABCDE.].       --- ABCDE not wrapped
;  [1234567]8       E=end,   behind buffer      W write pointer
;  [BR....W]E       B=begin, buffer             R read pointer
;   W>R: LOF = (W-R) = (7-2) = 5
;
;  [E..ABCD].       --- ABCDE wrapped around
;  [1234567]8
;  [BW.R...]E
;   R>W: LOF = (E-R)+(W-B) = (8-4)+(2-1) =  4 + 1 = 5
;            = (W-R)+(E-B) = (2-4)+(8-1) = -2 + 7 = 5
;               W-R is negative, must add buffer length
LOFDEV
        LDD     WRITPT             ; get read address
        SUBD    READPT
        BPL     LOF_1              ; positive: no wrap
        ADDD    #(BUFEND-BUFFER)   ; wrap
LOF_1
        RTS

; ------------------------------------------------------------
; placing the I/O buffer at the end allows omitting these bytes from loading
BUFFER  FILL $00,64     ; buffer of 64 bytes
BUFEND                  ; behind buffer
MEMSET  $*              ; same as BUFEND, first free address, for MEMSET

        END
```

A similar example is "`STAT:`", a device which counts the occurrence of each character sent to it. After installing is, one can `LIST "STAT:"` a program to it and later sequentially read the number of times each character occurred in the listing. For this purpose the device maintains a buffer of 256 16-bit counters, which can be read byte by byte. Thus, opening it for input and reading the first two bytes (high, low) yields the count of `CHR$(0)` sent to the device, `CHR$(1)` is returned in the next two bytes and so on until the last bytes 511 and 512 define the number of occurrences of `CHR$(255)`. Each `OPEN` for output resets the counting array, an `OPEN` for input resets the reading index to the start of he array.

The example application just sends 3 `A`'s, 2 `B`'s and one `C` as well as a `CHR$(13)` and `CHR$(10)` at the end of the `PRINT` statement. After running it once, you can directly call RUN 150 e.g. after listing a program with `LIST "STAT:"`.

```
10 REM --- Epson HX-20      ---
20 REM --- M. Hepperle 2024 ---
21 REM Installs a device "STAT:".
22 REM Writing to it counts the
23 REM number of occurrances of
24 REM each character code (0...255).
25 REM Reading returns 256*2 bytes
26 REM (high,low) which represent the
27 REM accumulated number of each character.
28 REM One can use LIST "STAT:" to count
29 REM how often each character occurs.
30 REM --- adjust BASIC starting address
40 MEMSET &HCB3
50 REM --- load the code bytes
60 GOSUB 350
70 REM --- install driver
80 GOSUB 450
90 REM --- application example
100 OPEN "O",#1,"STAT:"
110 FOR I%=1 TO 150
120 PRINT#1,CHR$(0)+"AAABBC"
130 NEXT I%
140 CLOSE #1
145 REM --- entry e.g. after LIST "STAT:"
150 PRINT "Finding maximum..."
160 MX=0
170 OPEN "I",#1,"STAT:"
180 FOR I%=0 TO 255
190  H$=INPUT$(1,#1) : L$=INPUT$(1,#1)
200  Y=ASC(H$)*256+ASC(L$)
210  IF Y>MX THEN MX=Y
220 NEXT I%
230 CLOSE #1
240 GCLS
250 OPEN "I",#1,"STAT:"
260 FOR I%=0 TO 127
270  H$=INPUT$(1,#1) : L$=INPUT$(1,#1)
280  Y%=31*(1-(ASC(H$)*256+ASC(L$))/MX)
290  LINE(I%,31)-(I%,Y%),PSET
300 NEXT I%
310 CLOSE #1
320 SOUND 33,2
330 C$=INPUT$(1)
340 END
350 REM --- Hex Code Loader ---
360 N%=0
370 READ C$
380 IF C$="DONE" THEN 430
```

```
390 N%=N%+1 : IF N%=8 THEN PRINT "."; : N%=0
400 C%=VAL("&H"+C$)
410 IF LEN(C$)=4 THEN A%=C% : GOTO 370
420 POKE A%,C% : A%=A%+1 : GOTO 370
430 PRINT
440 RETURN
450 REM --- Device Installer ---
460 DCBTAB%=&H0657
470 FOR A%=DCBTAB% TO DCBTAB%+30 STEP 2
480 C%=PEEK(A%)*256+PEEK(A%+1)
490 IF C%=&H0A40 THEN GOTO 550
500 IF C%=&H0000 THEN GOTO 520
510 NEXT A%
520 IF A%>DCBTAB%+28 THEN GOTO 570
530 POKE A%,&H0A : REM HIGH
540 POKE A%+1,&H40 : REM LOW
550 PRINT "STAT: @";A%;"installed"
560 RETURN
570 PRINT "Cannot install STAT:"
580 STOP
2141 DATA 0A40,53,54,41,54,30,0A,5A,0A,78,0A,79,0A,8F,0A,9F,0A,AB,00
2142 DATA 00,00,00,00,00,14,00,80,B6,06,8A,81,10,27,10,CE,0A,B1,86,FF
2143 DATA 6F,00,6F,01,08,08,4A,81,FF,26,F5,CE,0A,B1,FF,0C,B1,39,39,7F
2144 DATA 00,F5,FE,0C,B1,8C,0C,B1,27,07,A6,00,08,FF,0C,B1,39,7A,00,F5
2145 DATA 39,36,33,4F,05,C3,0A,B1,18,EC,00,F3,0A,AF,ED,00,39,5F,FE,0C
2146 DATA B1,8C,0C,B1,27,01,39,5A,39,CC,00,02,39,00,01,DONE
```

Assembler source code:

```
10 REM --- Epson HX-20      ---
20 REM --- M. Hepperle 2018 ---
21 REM Installs a device "STAT:".
22 REM Writing to it counts the
23 REM number of occurrances of
24 REM each character code (0...255).
25 REM Reading returns 256*2 bytes
26 REM (high,low) which represent the
27 REM accumulated number of each character.
28 REM One can use LIST "STAT:" to count
29 REM how often each character occurs.
30 REM --- adjust BASIC starting address
40 MEMSET &HCB3
50 REM --- load the code bytes
60 GOSUB 350
70 REM --- install driver
80 GOSUB 450
90 REM --- application example
100 OPEN "O",#1,"STAT:"
110 FOR I%=1 TO 300
120 PRINT#1,CHR$(0)+"AAABBC"
130 NEXT I%
140 CLOSE #1
145 REM --- entry e.g. after LIST "STAT:"
150 PRINT "Finding maximum..."
160 MX=0
170 OPEN "I",#1,"STAT:"
180 FOR I%=0 TO 255
190  H$=INPUT$(1,#1) : L$=INPUT$(1,#1)
200  Y=ASC(H$)*256+ASC(L$)
210  IF Y>MX THEN MX=Y
220 NEXT I%
230 CLOSE #1
240 GCLS
250 OPEN "I",#1,"STAT:"
260 FOR I%=0 TO 127
270  H$=INPUT$(1,#1) : L$=INPUT$(1,#1)
280  Y%=31*(1-(ASC(H$)*256+ASC(L$))/MX)
```

```
290  LINE(I%,31)-(I%,Y%),PSET
300 NEXT I%
310 CLOSE #1
320 SOUND 33,2
330 C$=INPUT$(1)
340 END
350 REM --- Hex Code Loader ---
360 N%=0
370 READ C$
380 IF C$="DONE" THEN 430
390 N%=N%+1 : IF N%=8 THEN PRINT "."; : N%=0
400 C%=VAL("&H"+C$)
410 IF LEN(C$)=4 THEN A%=C% : GOTO 370
420 POKE A%,C% : A%=A%+1 : GOTO 370
430 PRINT
440 RETURN
450 REM --- Device Installer ---
460 DCBTAB%=&H0657
470 FOR A%=DCBTAB% TO DCBTAB%+30 STEP 2
480 C%=PEEK(A%)*256+PEEK(A%+1)
490 IF C%=&H0A40 THEN GOTO 550
500 IF C%=&H0000 THEN GOTO 520
510 NEXT A%
520 IF A%>DCBTAB%+28 THEN GOTO 570
530 POKE A%,&H0A : REM HIGH
540 POKE A%+1,&H40 : REM LOW
550 PRINT "STAT: @";A%;"installed"
560 RETURN
570 PRINT "Cannot install STAT:"
580 STOP
2141 DATA 0A40,53,54,41,54,30,0A,5A,0A,78,0A,79,0A,8F,0A,9F,0A,AB,00
2142 DATA 00,00,00,00,00,14,00,80,B6,06,8A,81,10,27,10,CE,0A,B1,86,FF
2143 DATA 6F,00,6F,01,08,08,4A,81,FF,26,F5,CE,0A,B1,FF,0C,B1,39,39,7F
2144 DATA 00,F5,FE,0C,B1,8C,0C,B1,27,07,A6,00,08,FF,0C,B1,39,7A,00,F5
2145 DATA 39,36,33,4F,05,C3,0A,B1,18,EC,00,F3,0A,AF,ED,00,39,5F,FE,0C
2146 DATA B1,8C,0C,B1,27,01,39,5A,39,CC,00,02,39,00,01,DONE
```

16.2. Some Details about HX-20 BASIC (Microsoft BASIC)

16.2.1. The Floating Point Accumulator

Microsoft BASIC maintains a so called “floating point accumulator” (FPACC). This is a memory area used for intermediate results when working with 16-bit integer as well as single and double floating point numbers. It is also used to transfer a numeric parameter to a `USR` function. Its length is 8 bytes to hold a double precision floating point number. The arrangement of the bytes can be found in the BASIC reference manual. The location of the FPACC is at address `0x00D5` in RAM.

16.2.2. Memory allocation of Arrays

Allocation of a one-dimensional INTEGER array:

```
DIM N%(5)
A%=VARPTR(N%(0))
```

The `VARPTR` function returns the address of the first array element `(0)`. In memory this is followed the next element `(1)`.

Allocation of a two-dimensional INTEGER array:

```
DIM N%(5,6)
```

```
A%=VARPTR(N%(0,0))
```

The VARPTR function returns the address of the first array element (0,0). In memory this is followed the next element (1,0), i.e. the first index is incremented first.

Note: the examples above use the default OPTION BASE 0 setting. If OPTION BASE 1 is used, the first element is (1), respectively (1,1).

16.2.3. The BASIC Work Areas

Work Area (1)

Example memory dump:

```
 00000080 00 22 00 00 00 04 00 00 00 00 00 08 6C 08 69 1D ."..........l.i.
0085-0086:               <--->                  TypeInfo for data in FPACC
 00000090 7E 1D 80 00 00 00 00 0A 00 00 7D 65 0B 0C 1D 7C ~.........}e...|
009C-009D:                                    <---> HeadPointer:
                                                    address of address-
                                                    field of first line
009E-009F:                                          <---> StringSpace:
                                                          address of
                                                          string space
 000000A0 1D 84 1D 84 7D 89 7E 51 7E 51 7E 51 07 DA 07 DA ....}.~Q~Q~Q....
00A0-00A1:<---> NextFree? address of next free entry in string space
00A2-00A3:      <---> NextFree? address of next free entry in string space

 000000B0 07 D0 00 00 10 8D 00 00 0B 0B 00 00 01 1D 7E 1D ..............~.
00B8-00B9:                        <---> DataPointer: address of separator
                                                   of next line for READ
00BA-00BB:                              <---> TailPointer: address of last
                                                    line (after program was run)
 000000C0 82 00 00 00 1D 84 1D 80 00 00 00 00 00 00 04 BD ................
 000000D0 00 00 00 00 00 88 00 00 D8 00 00 00 00 00 00 01 ................
00D5-00DC:                        <------- FPACC -------> Floating Point
                                                          Accumulator
 000000E0 7E 51 00 00 00 00 E6 00 00 00 00 00 00 00 10 76 ~Q.............v
 000000F0 1D 7D 08 5D 00 00 0E 00 5F 00 B6 10 9B 7E B3 D8 .}.]...._....~..
```

Work Area (2)

Example memory dump:

```
 000005B0 00 00 00 88 DF 00 00 00 88 DF 00 00 00 00 00 00 ................
 000005C0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 000005D0 00 00 00 00 00 00 00 00 B4 F3 00 00 00 00 00 00 ................
 000005E0 00 00 7E 8C 70 7E 8C 70 7E 8C 70 7E A6 71 7E A6 ..~.p~.p~.p~.q~.
                <---0--> <---1--> <---2--> <---3--> <---- 39 error handlers
 000005F0 71 7E A6 71 7E A6 71 7E A6 71 7E A6 71 7E A6 71 q~.q~.q~.q~.q~.q
          -> <-------> <-------> <-------> <-------> <------->
 00000600 7E A6 71 7E A6 71 7E A6 71 39 A6 71 39 A6 71 39 ~.q~.q~.q9.q9.q9
          <-------> <-------> <-------> <-------> <-------> <-
 00000610 A6 71 39 A6 71 39 A6 71 39 A6 71 39 A6 71 39 A6 .q9.q9.q9.q9.q9.
          ----> <-------> <-------> <-------> <-------> <----
 00000620 71 39 A6 71 39 A6 71 39 A6 71 39 A6 71 39 A6 71 q9.q9.q9.q9.q9.q
          -> <-------> <-------> <-------> <-------> <------->
 00000630 39 A6 71 39 A6 71 39 A6 71 39 A6 71 39 A6 71 39 9.q9.q9.q9.q9.q9
          <-------> <-------> <-------> <-------> <-------> <-
 00000640 A6 71 39 A6 71 39 A6 71 39 A6 71 7E 88 DF 7E 88 .q9.q9.q9.q~..~.
          ----> <-------> <-------> <-------> <-------> <----
 00000650 DF 7E 88 DF 7E 88 DF 06 9C 06 B6 06 D0 06 EA 07 .~..~...........
          -> <--37--> <--38--> <-0-> <-1-> <-2-> <-3-> <- 16 DCB Addresses
 00000660 04 07 1E 07 38 00 00 00 00 00 00 00 00 00 00 00 ....8...........
          -> <-5-> <-6-> <-7-> <-8-> <-9-> <-0-> <-1-> <-
```

```
 00000670 00 00 00 00 00 00 00 00 22 00 00 00 00 00 00 00 ........".......
          -> <-3-> <-4-> <-5->
 00000680 00 00 00 00 00 00 00 00 00 00 20 01 FF 03 02 00 .......... .....
 00000690 38 4E 31 45 00 00 00 00 8C 70 00 00 4B 59 42 44 8N1E.....p..KYBD
069C:                                      <---------> Name of D0
 000006A0 10 B3 E4 B3 E4 A9 69 B7 30 B3 E4 B3 E4 B3 E4 B3 ......i.0.......
 000006B0 E4 00 00 00 00 80 53 43 52 4E 20 B3 E4 B3 E4 B3 ......SCRN .....
06B6:                      <--------->                 Name of D1
 000006C0 E4 B7 30 B3 E4 B3 E4 B3 E4 00 00 00 28 0E 1C 80 ..0.........(...
 000006D0 43 4F 4D 30 30 B0 6A B0 B3 B0 43 B1 11 B0 13 B0 COM00.j...C.....
06D0:     <--------->                                  Name of D2
 000006E0 0D B1 28 B1 28 04 00 0E 00 40 43 41 53 30 30 AD ..(.(....@CAS00.
06EA:                                   <--------->    Name of D3
 000006F0 8D AD DA AE 32 AE 70 AE 7C B3 E4 FE F8 00 00 00 ....2.p.|.......
 00000700 00 01 00 C1 43 41 53 31 30 AD 8D AD DA AE 32 AE ....CAS10.....2.
0704:                  <--------->                     Name of D4
 00000710 70 AE 7C B3 E4 FF 31 00 00 00 00 01 00 C1 50 41 p.|...1.......PA
071E:                                            <---- Name of D5
 00000720 43 30 10 B1 95 B2 00 B2 09 B1 28 B0 1F B0 1B B1 C0........(.....
          ---->                                        Name of D5 cont.
 00000730 28 00 00 00 00 00 00 C0 4C 50 54 30 20 B3 E4 B0 (.......LPT0 ...
0738:                           <--------->            Name of D6
 00000740 24 B3 E4 B0 2F B3 E4 B3 E4 B3 E4 B3 E4 00 18 0E $.../...........
 00000750 0E 00 00 FF 07 D5 88 20 32 30 30 30 00 00 00 00 ....... 2000....
 00000760 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
 00000770 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 29                )
 00000780 00 44 2C 42 44 2C 46 46 2C 37 30 2C 33 39 2C 46 .D,BD,FF,70,39,F
 00000790 46 2C 46 46 2C 30 30 00 00 00 00 00 00 00 00 00 F,FF,00.........
 000007A0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 000007B0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 000007C0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 000007D0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 000007E0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 000007F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000800 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000810 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000820 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000830 09 08 38 08 08 38 F4 6C 06 02 86 00 00 14 00 00 ..8..8.l........
 00000840 DE 41 D9 43 D8 5D 8C 22 08 E7 D7 C2 08 E7 FF B6 .A.C.].".........
 00000850 EF 7F 02 00 00 B3 58 00 00 00 00 00 41 25 00 00 ......X.....A%..
 00000860 00 00 00 00 00 00 00 00 00 00 00 00 01 7E 51 00 .............~Q.
 00000870 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000880 00 00 00 00 00 00 00 00 00 00 00 00 80 00 00 00 ................
 00000890 00 00 00 00 00 80 00 00 10 B3 00 07 DA 00 0A 1D ................
 000008A0 65 1D 7C 07 D5 00 00 00 00 05 07 DA 7D 75 00 10 e.|.........}u..
 000008B0 8D 00 00 10 9A 04 04 04 04 04 04 04 04 04 04 04 ................
08B5-                    <------ type code table A-Z ----
 000008C0 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04 8C ................
    -08CE:----------------------------------------> <- 10 addresses of
08CF-                                                  USR0-9 functions
                                     default 8C70: in BASIC ROM
 000008D0 70 8C 70 8C 70 8C 70 8C 70 8C 70 8C 70 8C 70 8C p.p.p.p.p.p.p.p.
 000008E0 70 8C 70 00 00 00 00 92 00 06 00 20 20 20 20 20 p.p........
    -08E2:------->
 000008F0 20 20 20 20 20 20 00 00 00 00 00 00 00 00 00 00       ..........
 00000900 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000910 06 D0 00 00 00 00 00 00 00 00 00 20 F9 68 00 00 ........... .h..
 00000920 26 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 &...............
 00000930 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000940 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000950 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000960 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000970 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000980 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 00000990 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 000009A0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
 000009B0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
```

```
000009C0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
000009D0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
000009E0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
000009F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
00000A00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
00000A10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
00000A20 00 00 00 00 00 00 00 FF 00 14 04 08 00 00 00 00 ................
00000A30 00 00 01 00 00 39 00 00 01 00 00 01 01 00 00 01 .....9..........
```

17. Using a Printer

An Epson P-40 printer (or any other printer with serial interface) can easily be connected to the RS-232C port of the HX-20. However, as the buffer of the P-40 is only 2 bytes, data transfer will only work properly if you wire the cable for hardware handshaking. This requires the connection of the printer handshake signal DTR to the HX-20 input signal DSR on pin 6 of the DIN connector.

You can then use commands like

```
LIST “COM0:(68N2B)”
```

to list a program on a printer set to 4800 baud and 8 data bits, no parity and two stop bits

Similarly, the statement

```
OPEN “O”,#1,”COM0:(68N2B)”
```

can be used in a program to open a file for output with subsequent `PRINT #1` statements. When done with printing, you should close the serial port with a `CLOSE #1` statement.

18. MH-20 – A Peripheral Emulator

The “MH-20” software runs on a PC and mimics two different peripherals for the HX-20:

- a display controller for text and graphics output and,
- a disk drive units with four disk drives (which equals two TF-20 drives).

While the display function is readily available with the HX-20, the disk drive emulation requires the setting of the switch SW4 to the ON position. This switch is accessible from the bottom of the HX-20. See the “Operating Manual”, page 2-1.

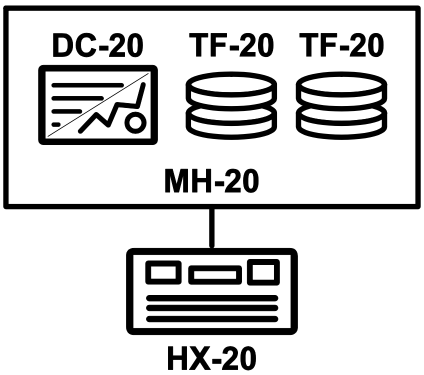


Figure 20: Schematic of the HX-20 with the MH-20 software.

18.1. Required Hardware for HX-20

The MH-20 program listens on the serial RS-232C port of your computer which must be connected to the high speed serial port of the HX-20. The emulator sets the serial port on the PC side to 38400 baud, 8 data bits, 1 stop bit, no parity and no handshaking. The wiring of a cable connecting the HX-20 with a standard IBM-AT-style D-SUB 9 pin male connector is shown in Figure 21. The common USB-RS-232C converter cables usually come with a matching male D-SUB connector and can be used.

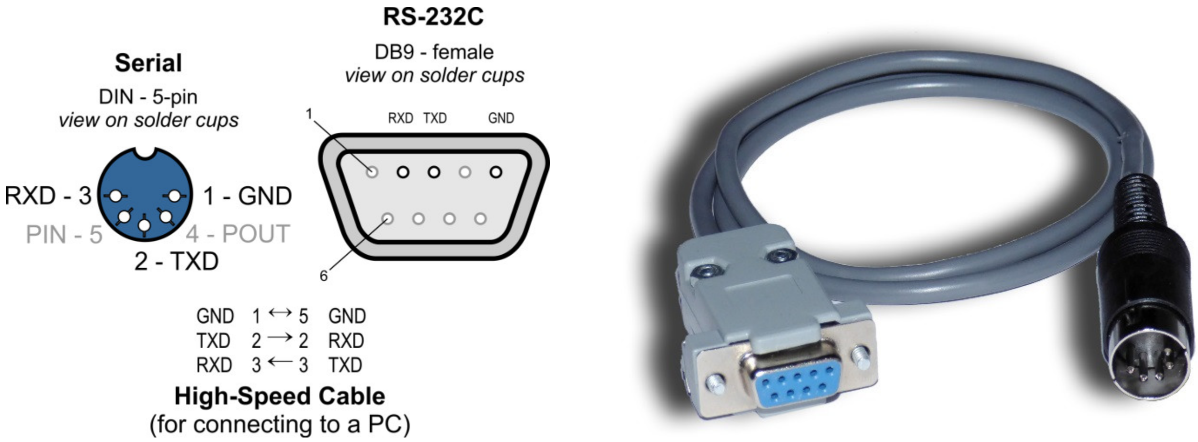


Figure 21: Cable to connect to HX-20 to a PC running the MH-20 screen and disk emulator. Only 3 wires are needed.

18.2. Using the MH-20 Software

MH-20 is written in Java and therefore is executable on many common platforms. You need a Java Runtime Environment (JRE) of Version 1.8 or higher. For the serial communication it relies on the jSSC (Java Simple Serial Connector) serial port communication library. This library includes system dependent hardware drivers for Linux, Mac OS/X, Solaris and Windows 32 as well as Windows 64.

You can start the simulator from a command line and supply these optional command line arguments:

- `-port PORT`

  default: PORT=COM1
  The device name of your serial port. You must use the proper syntax for your operating system, e.g. for higher port numbers under Windows: "/..//COM38", omit any trailing colon.

- `-width WIDTH`

  The width of the window in character columns. Default: WIDTH=80

- `-height HEIGHT`

  The height of the window in character rows. Default: HEIGHT=48

- `-diskconfig TYPE`

  The arrangement of disk drives. Use TYPE=0 for HX-20 (you can use the emulator also for the PX-8 and for this application other configurations are available)

- `-debug`

  Activates output of debug information.

In a Windows command prompt you can enter a command line for the HX-20 like

```
java -jar MH-20-Display-Controller.jar -port /..//COM38 -width 80 -height 24
```

Of course you can and should wrap this long command into a `.cmd` script file.

Under Linux you might have the problem that the serial port is usually not accessible by normal users. You have to be a super-user to work with it. Two options to handle this problem are listed below.

- Create a shell script (text file) e.g. “mh20dc.sh” with the desired command line options. Port access may require administrator rights. Therefore, you can use `sudo` which asks for the superuser password.

```
#!/bin/sh
sudo java -jar MH-20-Display-Controller.jar -port /dev/ttyS0
```

or

- You can also make your script file “mh20dc.sh” set the superuser-bit by itself:

```
sudo chmod +s mh20.sh
```

  Then your script would need no `sudo` command, but just the command line

```
#!/bin/sh
java -jar MH-20-Display-Controller.jar -port /dev/ttyS0
```

In both cases you can run the program by executing your script

```
./mh20.sh
```

18.3. Display Controller Emulation

The MH-20 program mimics an external display controller similar to the ones which were available in its day. One such device was the Oval HO-80 from Oval Ltd., a British company, which delivered its video output in form of UHF or PAL signals. Its screen was able to show 32×16 characters or 128×64 pixels in 4 colors or 128×96 pixels in monochrome.

My goal was not a faithful representation of this device (which I even don’t own) and its limitations but mainly to allow for easier reading and editing of programs for the HX-20. Editing programs on the small built-in LCD screen is not really fun – at least for me.

The HX-20 display system supports two operating modes: text mode and graphics mode. Both are partially implemented in the MH-20 software. The text mode offers all cursor movement and editing functions. The special graphics characters are also displayed, but no attempt has been made to implement user defined characters. I even don’t know whether the original display controller was able to handle those.

After the text mode worked sufficiently well for practical application I added some of the graphics functions. These allow clearing the screen (`GCLS`), drawing lines (`LINE`) and setting points (`PSET`) and inquiring the color of pixels (`POINT`).

Like with the original display controller, graphics and text screen are handled as exclusive entities. The MH-20 is either in text or in graphics mode - you cannot mix graphics and text.

However, to allow writing text in graphics mode I implemented an additional command to write a string of characters to the graphics screen. However, this requires the usage of a machine code subroutine to send out the proper data frames.

18.3.1. Applicable BASIC Keywords and Commands

Selecting the Output Device	Purpose
`SCREEN 1,0`	Send subsequent *text output* to the display controller.
`SCREEN 0,1`	Send subsequent *graphics output* to the display controller.
`SCREEN 0,0`	Send all subsequent output to the LCD display.
	The `SCREEN` command also selects the character set according to the current system settings.

Text Mode	Purpose
`CLS`	Clear the screen.
`PRINT`	Print output to the screen.
`LIST`	List the current program on the screen.
`WIDTH width,height`	Set the dimensions of the text screen in character cells.
`POS`	Return the horizontal position `x` of the cursor.
`CRSLIN`	Return the vertical position `y` of the cursor.
`LOCATE x,y,cursor`	Place the cursor at `(x,y)`, e.g. for a following `PRINT` statement.

Graphics Mode	Purpose
`GCLS`	Clear the graphics screen.
`COLOR fore,back,set`	Select foreground and background color for the given color set.
`PSET (x,y),index`	Set the pixel at `(x,y)` with the given color [0…3].
`PSET (x,y)`	Set the pixel at `(x,y)` with the current foreground color.
`PRESET (x,y)`	Set the pixel at `(x,y)` with the current background color.
`LINE (x1,y1)-(x2,y2),PSET`	Draw a line from `(x1,y1)` to `(x2,y2)` with the foreground color.
`LINE (x1,y1)-(x2,y2),PRESET`	Draw a line from `(x1,y1)` to `(x2,y2)` with the background color.
`POINT (x,y)`	Return the color index of the pixel at `(x,y)`. [0…3, 10…13]

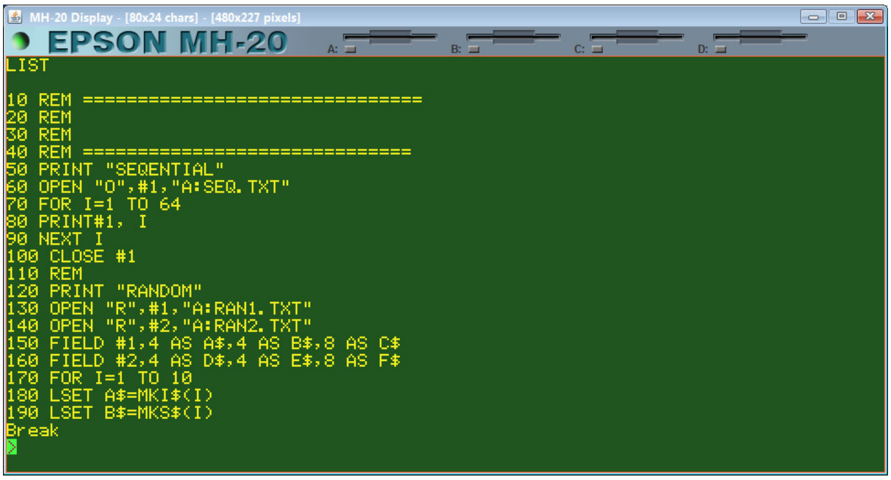


Figure 22: MH-20 in text mode after a `SCREEN 1,0` and a `LIST` command.
The caption bar shows the dimensions in character cells as well as in pixels.

Some differences from the Epson Specifications:

- Only a subset of the possible commands has been implemented. The program may handle unknown commands ungracefully.
- Text lines extending over multiple screen lines are not supported. Each line must fit on one line.
- In graphics mode, all dimensions have been doubled for better visibility – i.e. a line is drawn two pixels wide. The screen dimensions in pixels as shown in the title bar reflect this scaling and show the available coordinate space.
- The screen size can be considerably larger than that of the original display controller. Its size was limited to a text display of 16×32 characters respectively resolutions of 128×96 for monochrome graphics or 128×64 for color graphics.
- The size of the graphics screen is directly linked to the text screen size and cannot be changed. No movable window is implemented as this does not make too much sense on this larger screen.
- Both color sets of 4 colors each have been implemented as per specification. As they are only vaguely specified the default background color "green" has been made dark to have the default text color "yellow" stand out sufficiently. It is possible to use both color sets on the same screen, which was probably not possible on the original hardware.
- The `POINT` function returns 0…3 for colors in the color set 0, and 10…13 for colors from set 2. This allows distinguishing between the two color sets. The original hardware probably only returned values within 0…3.
- A context menu (right mouse button) allows copying the contents of the display to the clipboard. Depending on the current display mode, text and/or bitmap format are available.

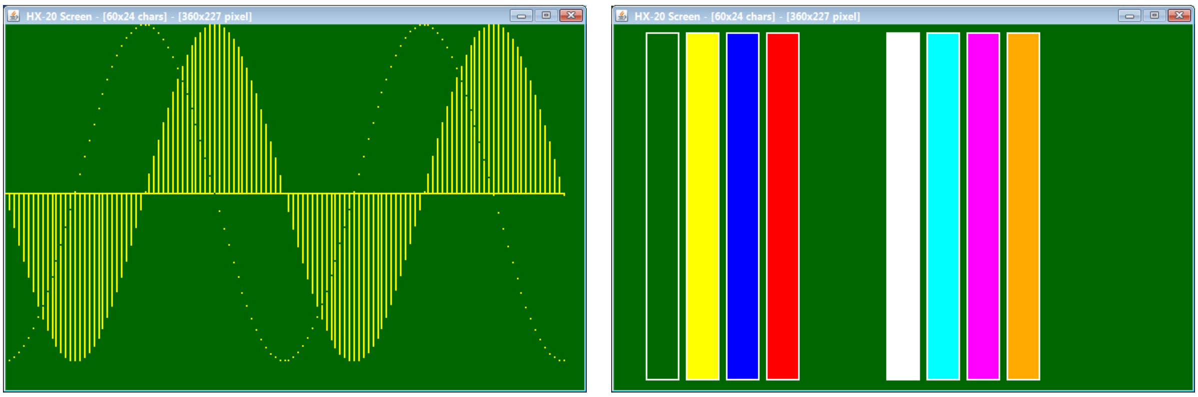


Figure 23: Result of running a simple plot programs.
Left: The same program runs on the internal LCD. For the external screen only a `SCREEN 0,1` command and individual scaling factors for the x- and y-direction have been added.
Right: The two color palettes (0 and 1) with 4 colors each, selected by using the `COLOR` command. The first bar (color index 0) represents the default background color of each color set.

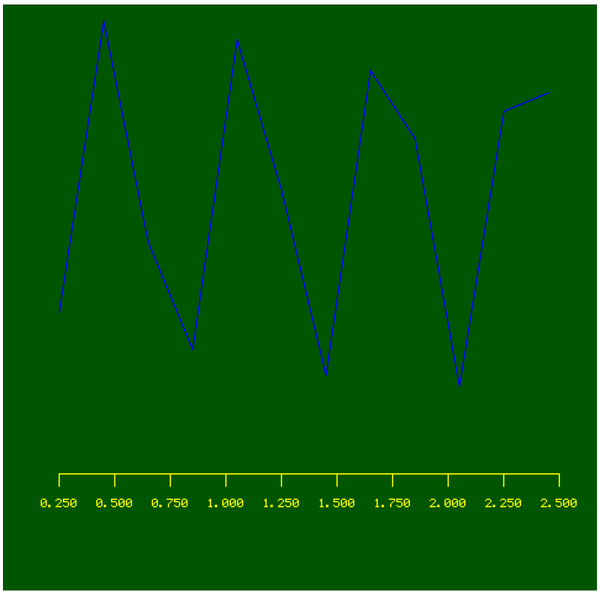


Figure 24: In contrast to the original Display Controller the software emulator can also display characters if a special machine language subroutine is used.

The example shown in Figure 24 uses a machine language subroutine to send a special data packet to the MH-20 Display Controller. The parameters of this subroutine are the X, and Y coordinates as well as the string to output (up to 32 characters). These are packed into a string because `USR` functions only allow for one parameter.

```
                        ; a09 outchar.asm -loutchar.lst
                        ; python LST2BAS.py outchar.lst > outchar.bas
                               OPT H01

                                ORG     $0A40

                        BUFLEN  EQU     32        ; max. string length
                        SERSND  EQU     $FF70     ; operating system function
                        ; BASIC floating point accumulator to return result
                        FPTYP   EQU     $0085     ; 2 bytes: type of # in FPACC
                        FPACC   EQU     $00D5     ; floating point accumulator

                        ; Epson HX-20
                        ; USR function for sending a string with leading
                        ; 16-bit x-y coordinates via serial interface.
                        ; The string may have up to BUFLEN characters.
                        ; Returns the length of the output string
                        ; (minus the 4 leading bytes)
                        ;
                        ; Usage:
                        ; DEFUSR1=&H0A40
                        ; DEFFNLO$(X%)=CHR$(X% AND 255)
                        ; DEFFNHI$(X%)=CHR$((X%\256) AND 255)
                        : X=25 : Y=50
                        ; M$=FNHI$(X)+FNLO$(X)+FNHI$(Y)+FNLO$(Y)
                        ; L=USR1(M$+"Hello World")
                        ;
                        ; X points to string descriptor:
                        ; 0,X: length of string, must be >4
                        ; 1,X: address of string
0A40 8103                       CMPA    #$03      ; do we have a string?
0A42 2653                       BNE     OOPS      ; no: leave
0A44 E600                       LDAB    0,X       ; length of string -> B
0A46 5A                         DECB              ; minus 1 = data length
0A47 F70A9E                     STAB    CNT       ; store data length
```

```
0A4A C003               SUBB    #$03      ; minus X,Y
0A4C 2F49               BLE     OOPS      ; less than one character?
0A4E C120               CMPB    #BUFLEN   ; up to BUFLEN chars
0A50 2F02               BLE     LENOK
0A52 C620               LDAB    #BUFLEN   ; min(N,BUFLEN)
                        ;
0A54 9602       LENOK:  LDAA    $02       ; return data type: integer
0A56 9785               STAA    FPTYP     ; type of # in FPACC
0A58 4F                 CLRA              ; store integer in FPACC+2,3
0A59 97D7               STAA    FPACC+2   ; high byte = 0
0A5B D7D8               STAB    FPACC+3   ; low byte  = length
                        ;
0A5D EE01               LDX     1,X       ; address of string -> X
0A5F A600               LDAA    0,X
0A61 B70A9F             STAA    XPNT      ; high byte of X
0A64 A601               LDAA    1,X
0A66 B70AA0             STAA    XPNT+1    ; low byte
0A69 A602               LDAA    2,X
0A6B B70AA1             STAA    YPNT      ; high byte of Y
0A6E A603               LDAA    3,X
0A70 B70AA2             STAA    YPNT+1    ; low byte

0A73 37                 PSHB
0A74 CC0AA3             LDD     #CHAR     ; starting address of CHAR
0A77 FD0A98             STD     CPTR      ; store pointer
0A7A 33                 PULB              ; length of string -> B

                        ; address of source char is (X+4)
                        ; address of destination is in CPTR

0A7B A604       NEXT:   LDAA    4,X       ; get next character   A=*(X+4)
0A7D 3C                 PSHX              ; save source address
0A7E FE0A98             LDX     CPTR      ; destination address  X=CPTR
0A81 A700               STAA    0,X       ; store character code *CPTR=A
0A83 38                 PULX
0A84 08                 INX               ; increment source address
0A85 7C0A99             INC     CPTR+1    ; increment low byte of target
0A88 2803               BVC     NOVER     ; V=0: no overflow
0A8A 7C0A98             INC     CPTR      ; else: increment high byte
0A8D 5A         NOVER   DECB              ; decrement character count
0A8E 26EB               BNE     NEXT      ; next character

0A90 4F                 CLRA              ; A=0: send a packet
0A91 CE0A9A             LDX     #PACKET   ; address of PACKET
                ;       FCB     $00       ; DEBUG: force HX-20 Trap!
0A94 BDFF70             JSR     SERSND    ; send packet
0A97 39         OOPS:   RTS

0A98 FFFF       CPTR:   FCB     $FF,$FF   ; pointer to current CHAR
                ;
                PACKET:
0A9A 00         OP:     FCB     $00       ; 0: send
0A9B 30         DID:    FCB     $30       ; destination ID
0A9C 20         SID:    FCB     $20       ; source ID
0A9D EE         FCN:    FCB     $EE       ; my own function code
0A9E 03         CNT:    FCB     $03       ; data length - 1

                DATA:                     ; the actual payload
0A9F FFFF       XPNT:   FCB     $FF,$FF   ; X
0AA1 FFFF       YPNT    FCB     $FF,$FF   ; Y
0AA3 FFFFFFFFFFFFFF CHAR: FILL  $FF,BUFLEN   ; buffer[BUFLEN]
0AAA FFFFFFFFFFFFFF
0AB1 FFFFFFFFFFFFFF
0AB8 FFFFFFFFFFFFFF
0ABF FFFFFFFF
                        END
```

The corresponding BASIC loader and test program as created by the python script `LST2BAS.py` is:

```
10 REM --- Epson HX-20      ---
20 REM --- String Output to MH-20 ---
30 REM --- M. Hepperle 2018 ---
40 GOSUB 70
50 PRINT USR1(CHR$(0)+CHR$(32)+CHR$(0)+CHR$(64)+"Hello World")
60 STOP
70 REM --- Hex Code Loader  ---
80 N%=0
90 MEMSET &HAC3
100 READ C$
110 IF C$="DONE" THEN 160
120 N%=N%+1 : IF N%=8 THEN PRINT "."; : N%=0
130 C%=VAL("&H"+C$)
140 IF LEN(C$)=4 THEN A%=C% : GOTO 100
150 POKE A%,C% : A%=A%+1 : GOTO 100
160 PRINT
170 DEFUSR1=&H0A40
180 RETURN
190 DATA 0A40,81,03,26,53,E6,00,5A,F7,0A,9E,C0,03,2F,49,C1,20,2F,02
191 DATA C6,20,96,02,97,85,4F,97,D7,D7,D8,EE,01,A6,00,B7,0A,9F,A6,01
192 DATA B7,0A,A0,A6,02,B7,0A,A1,A6,03,B7,0A,A2,37,CC,0A,A3,FD,0A,98
193 DATA 33,A6,04,3C,FE,0A,98,A7,00,38,08,7C,0A,99,28,03,7C,0A,98,5A
194 DATA 26,EB,4F,CE,0A,9A,BD,FF,70,39,FF,FF,00,30,20,EE,03,FF,FF,FF
195 DATA FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF
196 DATA FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,FF,DONE
```

18.4. Disk Drive Emulation

The second function of the MH-20 program is the emulation of disk drive units. This gives you four simulated floppy disk drives.

Note that a tooltip with a short directory listing is shown when you hover the mouse pointer over one of the drive images.

18.4.1. Technical Background

The Epson TF-20 dual 5-¼" disk drive unit is actually a small computer which runs a variant of the CP/M operating system. It communicates with the HX-20 over a “high-speed” serial connection at 38400 baud using the EPSP Protocol developed by Epson. This protocol underwent some extensions for later Epson computers and is only sparingly documented.

When the HX-20 boots up, it first asks the TF-20 for a short boot loader program. After this has been received, it asks for a longer machine language program containing the code to extend the BASIC of the HX-20. This program implements the additional or modified keywords and commands to support the disk drive.

The extension code is loaded into the memory of the HX-20. Its actual location depends on the size of the RAM installed in the HX-20. Therefore, the HX-20 also asks the TF-20 to relocate the code according to its memory configuration. Thus, the TF-20 has to recalculate the affected addresses in the code before sending it to the HX-20. The MH-20 emulator supports all logical disk functions as required for operation of the HX-20.

18.4.2. The Emulation

The MH-20 emulator emulates two floppy units, i.e. a total of four disk drives. These are mapped to four directories:

DISK_A
DISK_B
DISK_C
DISK_D

Each directory contains individual files.

While the original floppy disks have a limited capacity, the capacity of the mapped drives is only limited by the mass storage capacity of the host computer. Of course it makes sense to limit the number of files in each directory to a reasonable number.

For this purpose each file is directly represented by a disk file on the host computer - no disk image files are used. Therefore, physical disk functions, like formatting and sector reading/writing, do not make much sense and produce no result.

The main applications of the disk emulation are

- saving and loading programs,
- creating, writing and, reading of data files.

18.4.3. Applicable BASIC Keywords and Commands

Keyword	Purpose
`CLOSE`	close file(s)
`CVI, CVD, CVS`	convert a string to numeric data
`DSKF`	return free space on disk (has no effect, always returns 320 KB)
`DSKI$`	direct input of one record (has no effect, returns "Read Error")
`DSKO$`	direct output of one record (has no effect, returns "Disk write protected")
`EOF`	return end of file code
`FIELD`	define fields for the record buffer used by random access file
`FILES`	display disk directory
`FILNUM`	define number of FCBs in advance
`FRMAT`	format a disk (has no effect)
`GET`	read one record from random access file
`INPUT#`	read data item from sequential access file
`INPUT$`	read a string from a sequential access file
`KILL`	delete a file
`LINE INPUT#`	read line of characters from sequential access file
`LIST`	output a program listing to a file
`LOAD`	load a program from a file
`LOADM`	load a machine language program from a file
`LOC`	return the current record number of a file

`LOF`	return the largest record number of a file
`LSET`	store data in file buffer for random access file
`MERGE`	merge a program into current program
`MKI$, MKD$, MKS$`	convert numeric data to a string
`NAME`	rename a file
`OPEN`	open a file
`PRINT#`	print data to a sequential access file
`PRINT# USING`	print formatted data to a sequential access file
`PUT`	write one random record from file
`RESET`	enable replacement of disk
`RSET`	store data in file buffer for random access file
`RUN`	load and execute a program from disk
`SAVE`	save a program to a file in binary or ASCII format
`SAVEM`	save memory range to a file
`SYSGEN`	create a new system disk (has no effect)
`WHILE...WEND`	conditional loop statement

Note that

- record numbers are 0-based
- each record is 128 bytes long
- the `FIELD` statement defines the structure of a complete record
- the `PUT` and `GET` statements write resp. read a complete record

18.5. Credits

Copyright notice for the serial library used in MH-20:

```
/* jSSC (Java Simple Serial Connector) - serial port communication library.
 * © Alexey Sokolov (scream3r), 2010-2014.
 *
 * This file is part of jSSC.
 *
 * jSSC is free software: you can redistribute it and/or modify
 * it under the terms of the GNU Lesser General Public License as published by
 * the Free Software Foundation, either version 3 of the License, or
 * (at your option) any later version.
 *
 * jSSC is distributed in the hope that it will be useful,
 * but WITHOUT ANY WARRANTY; without even the implied warranty of
 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
 * GNU Lesser General Public License for more details.
 *
 * You should have received a copy of the GNU Lesser General Public License
 * along with jSSC.  If not, see <http://www.gnu.org/licenses/>.
 *
 * If you use jSSC in public project you can inform me about this by e-mail,
 * of course if you want it.
 *
 * e-mail: scream3r.org@gmail.com
 * web-site: http://scream3r.org | http://code.google.com/p/java-simple-serial-connector/
 */
```

19. Map of the System RAM

The HX-20 system uses the lower part of its RAM for storage of various system variables. When writing assembler programs it is useful to have a complete picture of the RAM usage. The following Table was compiled from the Technical Manual.

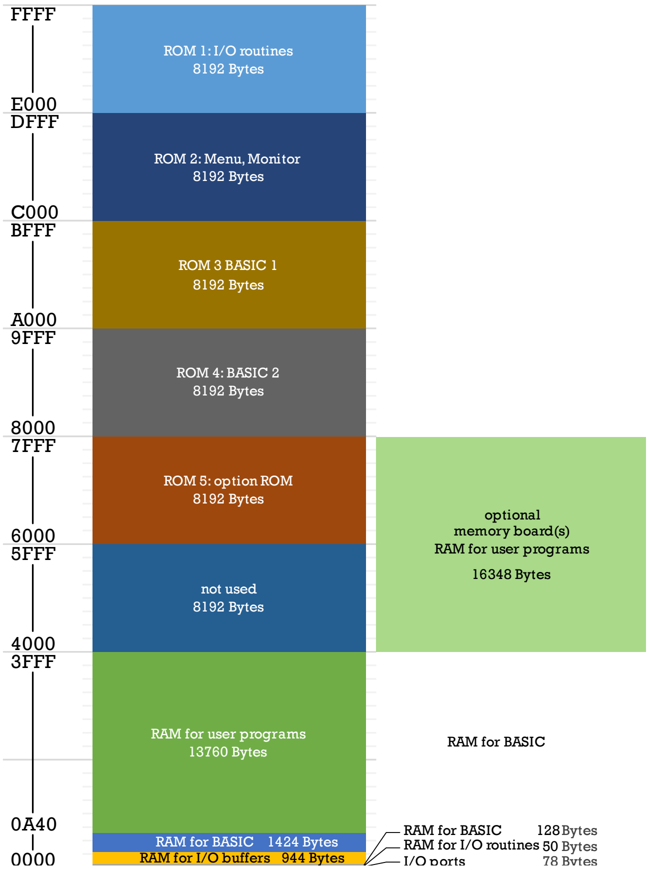


Figure 25: Global memory map of the HX-20 system.

Usage	Addr.	Len.	Name
Clock I/O ports	40	1	seconds
	41	1	alarm seconds
	42	1	minutes
	43	1	alarm minutes
	44	1	hours
	45	1	alarm hours
	46	1	day
	47	1	date
	48	1	month
	49	1	year
	4A	1	control register A
	4B	1	control register B
	4C	1	control register C
	4D	1	control register D
Clock	4E	50	RTC RAM
Basic interpreter	80	128	
Interrupt processing	100	3	INTCLK
	103	3	INTEXT
	106	3	TRAP
	109	3	IRQ1 SCI
	10C	3	IRQ1 TOF
	10F	3	IRQ1 OCF
	112	3	IRQ1 ICF
	115	3	IRQ1 == INTCLK
	118	3	SW1
	11B	3	NMI

Usage	Addr.	Len.	Name
Vectors	11E	2	user defined chars.
	120	2	BRKADR
	122	2	MENADR MENU
	124	2	PAUADR BREAK
	126	2	CT3ADR PF3
	128	2	CT3ADR PF4
	12A	2	CT3ADR PF5
	12C	2	CT3ADR PF5rmbadr
	12E	2	PRMCNT
	130	2	WAKADR
	132	2	POFADR
	134	2	BSWTAD
	136	2	BSWBAD
	138	2	no name
Menu and link tables	13A	2	BITMP0
	13C	2	BITMP1
	13E	2	LNKTBL
Keyboard	140	1	KSTKSZ
	141	1	KICNT1
	142	1	KICNT2
	143	2	KICNTM
	145	10	NEWKTB
	14F	10	OLDKTB
	159	10	CHKKTB
	163	2	KYISAD
	165	1	KYISFL

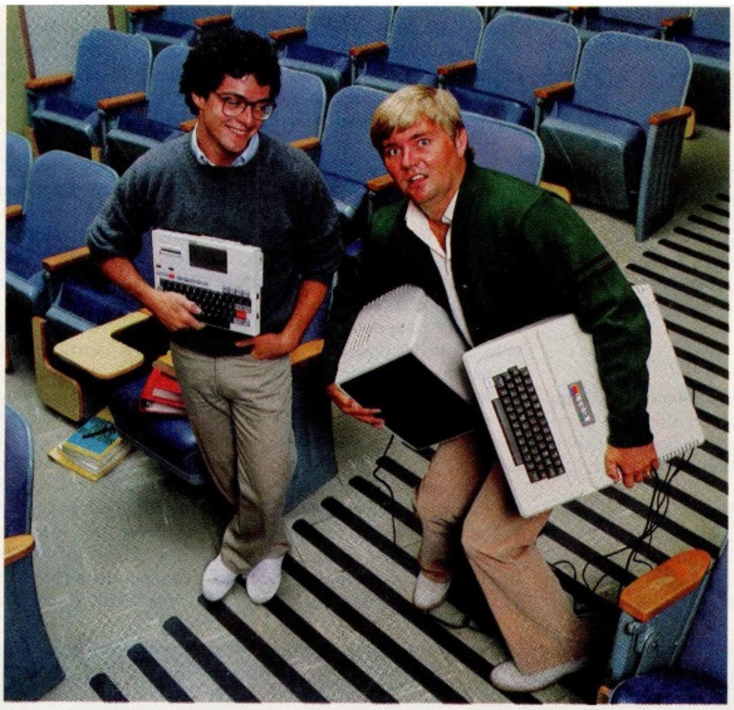
Usage	Addr.	Len.	Name
	166	1	KYISCN
	167	1	KYISPN
	168	1	STKCNT
	169	1	KEYMOD
	16A	1	ONKFLG
	16B	1	KPRFLG
	16C	1	KEYRPT
	16D	2	CKEYRD
	16F	18	KYISTK
	181	8	CHRSTK
	189	7	no name
Microprinter	190	6	CHRPTN
	196	1	COLCNT
	197	24	CHRDAT
RS 232C	1AF	2	RSBAUD
	1B1	2	RSCRC
	1B3	2	RSBCC
	1B5	1	RSBITL
	1B6	1	RSMODS
	1B7	1	RSSTSR
	1B8	2	RSBFAD
	1BA	2	RSBFBT
	1BC	2	RSBFSZ
	1BE	2	RSINP
	1C0	2	RSOUP
	1C2	2	RSDCNT
High Speed Serial	1C4	1	SRFMT
	1C5	1	SRDDEV
	1C6	1	SRSDEV
	1C7	1	SRFNC
	1C8	1	SRSIZ
	1C9	1	SRACKC
	1CA	1	SRTRCN
	1CB	1	SRTIMO
	1CC	1	SRETMO
	1CD	1	SRATMO
	1CE	1	SRMODE
	1CF	1	STETDL
	1D0	1	SRBLCN
	1D1	1	SRERMD
	1D2	1	SRRVFL
	1D3	2	SREIX
External Cassette	1D5	1	CSMOD
	1D6	2	CSBLNO
	1D8	2	CSBCC
	1DA	2	CSBLSZ
	1DC	1	CSSTP
	1DD	1	CSSTS
	1DE	2	CSBFAD
	1E0	2	CSBFRT
	1E2	2	CSBFSZ
	1E4	2	CSBFIP
	1E6	2	CSBFOP
	1E8	2	CSBFCM
	1EA	1	CSRDTR
	1EB	1	CSRDCN
Internal Cassette	1EC	1	MSMOD
	1ED	2	MSGLNO
	1EF	2	MSBCC
	1F1	2	MSBLSZ
	1F3	1	MSBSTP
	1F4	1	MSSTS
	1F5	2	MSBFAD
	1F7	2	MSBFBT
	1F9	2	MSBFSZ
	1FB	2	MSBFIP
	1FD	2	MSBFOP
	1FF	2	MSBFCM
	201	1	MSRDIR
	202	1	MSRDCN
	203	2	MSCNTR

Usage	Addr.	Len.	Name
	205	1	MSMNCM
	206	1	MSTOFCN
	207	1	MSPLMD
ROM Cartridge	208	1	PRMSTS
	209	2	STAPRS
	20B	2	FTADRS
	20D	2	EDADRS
Binary Dump/Load	20F	2	DLTPAD
	211	2	DLBTAD
	213	2	DLOPAD
	215	2	DLSTAD
	217	1	DLDVID
	218	1	DLSTS
	219	2	DLDVIX
RESERVED	21B	5	reserved
LCD	220	80	PSBUF
	270	2	SCRTOP
	272	2	SCRBOT
	274	2	DISTOP
	276	1	VSCRX
	277	1	VSCRY
	278	1	CURX
	279	1	CURY
	27A	1	LRMODE
	27B	1	UDMOD
	27C	1	CURMRG
	27D	1	SSPEED
	27E	1	DISPX
	27F	1	DISPY
	280	1	DISSTS
	281	5	no name
	286	6	CHRPTN
Screen work area	28C	20	no name
Monitor work area	2A0	48	no name
External Cass. Headers	2D0	1	CHBLID
	2D1	2	CHBLNO
	2D3	1	CHBLBU
	2D4	4	CID
	2D8	8	CFNAME
	2E0	8	CFTYPE
	2E8	1	CRTYPE
	2E9	1	CBMODE
	2EA	5	CBLNG
	2EF	5	no name
	2F4	6	CDATE
	2FA	6	CTIME
	300	6	no name
	306	2	CVOLN
	308	8	CSYSN
	310	20	no name
Internal Cass. Headers	324	1	MHBLID
	325	2	MHBLNO
	327	1	MHBLBU
	328	4	MID
	32C	8	MFNAME
	334	8	MFTYPE
	33C	1	MRTYPE
	33D	1	MBMODE
	33E	5	MBLNG
	343	5	no name
	348	6	MDATE
	34E	6	MTIME
	354	6	no name
	35A	2	MVOLN
	35C	8	CSYSN
	364	20	no name
	378	260	CASBUF
Total RAM used		**1148**	**bytes**

Table 6: Detailed RAM usage by the HX-20 operating system.

20. News and Commercial Announcements

Note: The following figures contain company and product names which are reproduced here only for historic documentation and archival purposes. These companies may not exist anymore and the products mentioned are surely not available anymore.



Which do you think is the more sophisticated computer?

Epson.

The big differences between the Epson HX-20 Notebook Computer (on the left) and the Apple Computer (on the right) are: 1) the HX-20 doesn't need a power cord, 2) the HX-20 weighs only about four pounds, and 3) the HX-20 costs a lot less money.

The Epson HX-20 Notebook Computer has a full-size keyboard, a built-in LCD screen, a built-in printer, 48K of combined RAM and ROM memory, and an internal power supply that will keep it running for over 50 hours. So you can do computing and word processing virtually anyplace you happen to be. Whereas, with the Apple Computer, you can only go as far as an extension cord will take you.

And on the HX-20, you get communications interfaces, upper and lower case letters, five program areas, a full 68 keys including an integrated numeric key pad, an internal clock/calendar, and the screen and printer. Standard. On the Apple, you pay something extra for each feature — if you can get them at all.

All of which makes the take-it-anywhere HX-20 perfect for business executives, salespeople, students, kids — anyone who's looking for an affordable, practical way into computing.

Portable. Powerful. Affordable. Sophisticated. The extraordinary HX-20 Notebook Computer. Find out just how extraordinary. Call (800) 421-5426, in California (213) 539-9140 for your nearest Epson computer dealer.

EPSON

EPSON AMERICA, INC.

Circle 177 on inquiry card.

BYTE March 1983 99

ROSE BOWL SCOREBOARD SNAFU DONE WITH PORTABLE COMPUTER

During January's Rose Bowl, a scoreboard prank by two CalTech students was made possible by two computers and radio modems. The students, who are now being prosecuted for trespassing, used an Epson HX-20 notebook-size portable computer with an RF modem to tap into an 8086 breadboard they'd attached between the scoreboard and its operators. The students put several messages on the scoreboard's scratch-pad area and finally changed the names of the teams to show CalTech trouncing rival MIT, instead of UCLA beating Illinois. The students later held a seminar called "Packet RF Control of Remote Digital Displays."

BYTE April 1984 9

Figure 26: Can these eyes lie? The dark color scheme of the HX-20 seems to have been composed specifically for this advertisement.

Figure 27: This ad in the February 1982 issue of "Practical Computing" obviously aims at British customers, following Winston Churchill's famous words.

Figure 28: And another extraordinary one lifted from the October 1982 issue of "Dr. Dobbs Journal".

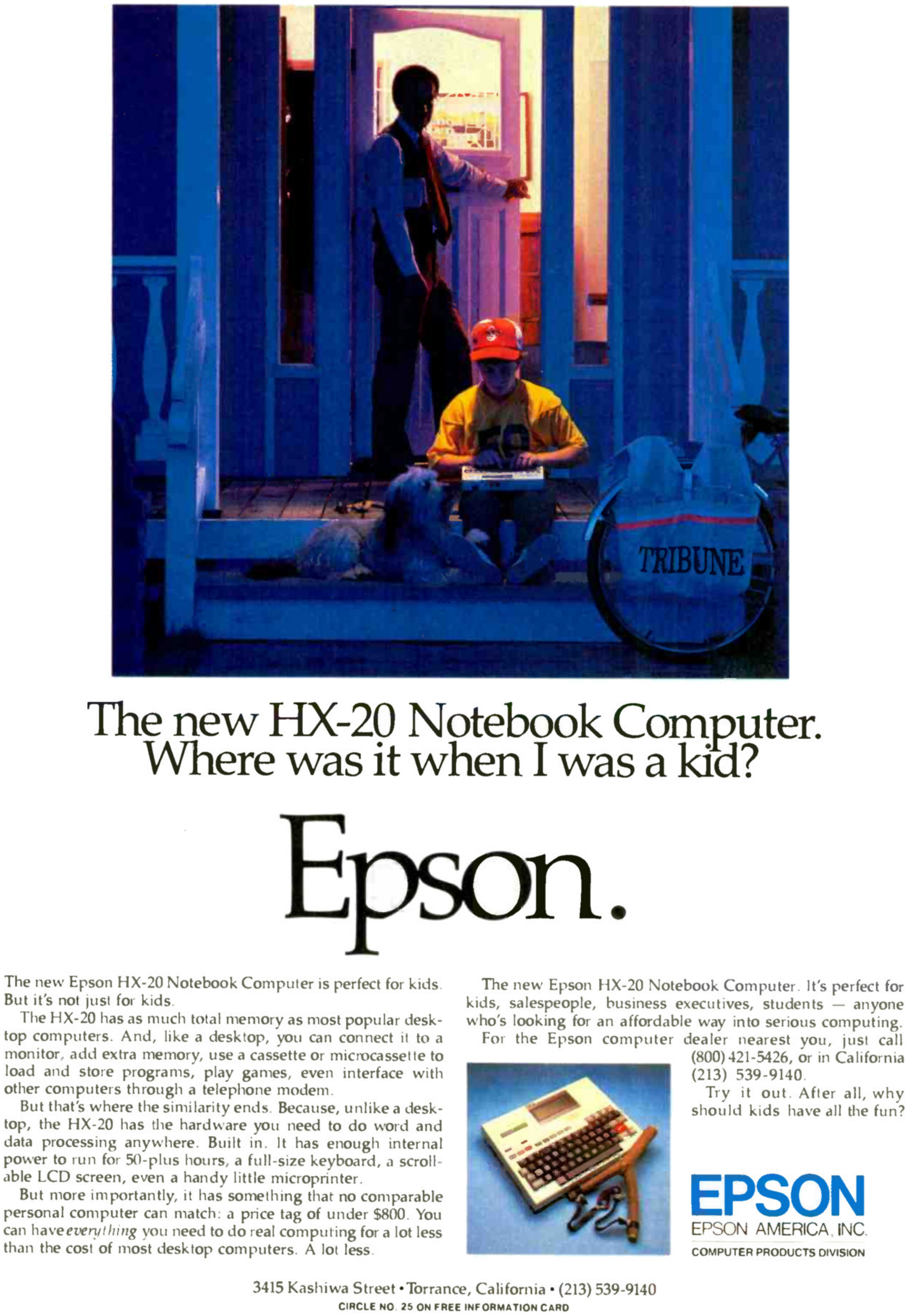


Figure 29: This ad was taken from the March 1983 issue of "CE".

HX 20 schon 'geknackt'

(Leserbrief von K. H. Kreeb, Worpswede, in c't 5/84)

Die 'interne Software' des HX-20, für die sich Herr Kreeb interessiert, ist schon seit längerer Zeit geknackt. Wir sind drei HX-Freaks und geben seit Sommer 1983 eine HX-20-Fachzeitschrift 'EPSILON' heraus. Diese erscheint 6 mal pro Jahr und wird momentan von über 400 Personen in ganz Europa abonniert. Daneben vertreiben wir eine HX-20-Dokumentation, die die Betriebsroutinen und Systempointer des HX erläutert und auflistet, ein sehr leistungsstarkes Textverarbeitungsprogramm, ein Debugger/Compactorprogramm und ein EPROM-Programmiergerät. Am 3. März 1984 veranstaltete EPSILON eine HX-Tagung, an der 60 Abonnenten teilnahmen, u. a. auch aus der Bundesrepublik und aus Österreich. Am 27. Oktober 1984 findet die zweite Tagung statt, die unter dem Generalthema 'Kommunikation mit EPSON-Computern' stehen wird.

Gerne senden wir Herrn Kreeb und allen, die sich interessieren, eine Probenummer zu.

Peter Addor, EPSILON,
Postfach 185,
CH-8704 Herrliberg-Zürich

c't 1984, Heft 6

Und wieder einmal 'HX-20 geknackt'

(Leserbriefe c't 5; 6, 7/84)

Mit Interesse habe ich die Briefe zum Thema 'HX-20' verfolgt. Daraus läßt sich schließen, daß wahrscheinlich die miserable Dokumentation der meisten Computerhersteller schon zum Standard erklärt wird. Beim HX-20 gibt es jedoch nicht mehr so viel zu knacken, da in dem von EPSON vertriebenen 'Technical Reference Manual' das Monitorprogramm mit vielen Beispielprogrammen in Assembler erklärt ist. Sicher bleiben noch einige Geheimnisse zu lüften, jedoch liegt der Verdacht nahe, daß auch User-Clubs ohne Erwähnung der Quelle aus diesem Fundus zehren. Allein der Preis von DM 300,— trübt die Freude an diesem ansonsten vorbildlichen Werk.

Knut Brenndörfer, Ismaning

c't 1984, Heft 8

Figure 30: The quest for finding more technical information shows up in letters to the German magazine c't.

c't 1984, Heft 2

c't 1984, Heft 3

c't 1984, Heft 9

Figure 31: The company "time-soft" had many special offers for HX-20 owners.

c't 1984, Heft 9

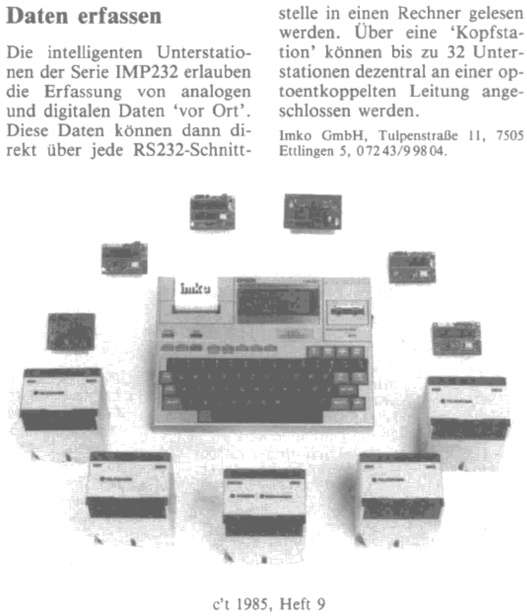
Figure 32: Besides a display controller, Mirwald also sold memory expansion boards for the HX-20.

HX-20 programmiert EPROMs

Das netzunabhängige Programmiergerät HXP2000 kann in Verbindung mit dem Epson-Computer HX20 alle gängigen EPROM-Typen programmieren. Zum Lieferumfang des Gerätes gehören ein (deutsches) Handbuch sowie eine menügesteuerte Software, die das Programmieren der ICs im Standard- oder Intelligent-Modus erlaubt. Das Programmiergerät HXP2000 kostet als Bausatz 440 DM, als Fertiggerät 560 DM.

SES-Electronic, Im Grund 17, 6920 Sinsheim, 07261/3264.

c't 1985, Heft 8



Daten erfassen

Die intelligenten Unterstationen der Serie IMP232 erlauben die Erfassung von analogen und digitalen Daten 'vor Ort'. Diese Daten können dann direkt über jede RS232-Schnittstelle in einen Rechner gelesen werden. Über eine 'Kopfstation' können bis zu 32 Unterstationen dezentral an einer optoentkoppelten Leitung angeschlossen werden.

Imko GmbH, Tulpenstraße 11, 7505 Ettlingen 5, 07243/99804.

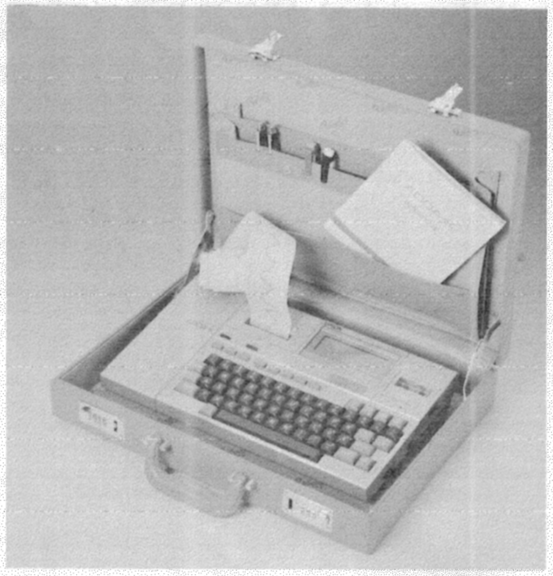
c't 1985, Heft 9

Figure 33: More accessories like EPROM programmer and data acquisition systems were available from 3rd parties.

Mobiles Messen

Um Meßwerte vor Ort zu erfassen und diese vom PC auswerten zu lassen, bietet CSM eine preiswerte Lösung an. Mit dem ADDA-K in Verbindung mit dem Epson HX-20 hat der Benutzer ein hochwertiges mobiles Meßwerteerfassungs- und Verarbeitungssystem zur Verfügung. Die Adda-K-Schnittstelle hat acht über Multiplexer anwählbare 12-Bit-Analogeingänge, je acht digitale Ein- und Ausgänge und ist direkt mit dem Systembus des HX-20 verbunden. Die serielle Schnittstelle des HX-20 bleibt bei dieser Lösung für andere Aufgaben frei. Der batteriegepufferte Meßwertspeicher ist von 32 KByte auf 128 KByte aufrüstbar. Das HX-20-Basic ist um einige Echtzeitbefehle erweitert worden, mit denen z. B. der Zeittakt für die A/D-Umsetzung und die Speicherrate jedes Analogeingangs programmiert werden können. Mit dem mitgelieferten Plott-Programm werden die aufgezeichneten Meßwerte auf dem im HX-20 eingebauten Minidrucker bereits vor Ort ausgegeben. Die ADDA-K-Schnittstelle kostet mit 64 KByte Meßwertspeicher knapp 3300 DM.

CSM
Mühlwiesenstr. 1
7024 Filderstadt-Sielmingen
☏ 0 71 58/6 48 47



So handlich ist die Kombination ADDA-K und Epson HX-20

mc 1/1987

Figure 34: And, another 12-bit A/D data acquisition system with digital I/O ports from CSM.

Figure 35: Another video controller was developed by KK Systems in the north of Germany.

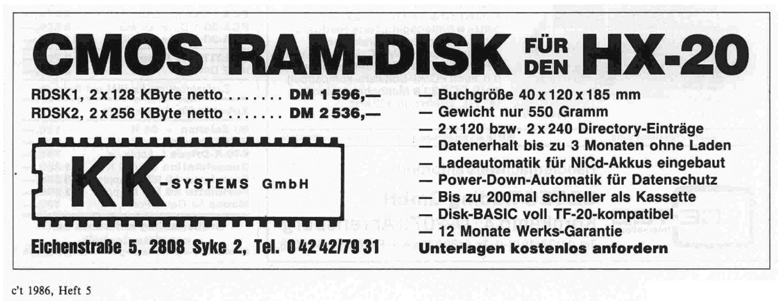


Figure 36: Also available from KK Systems: RAM disks for the HX-20.

Figure 37: Obviously, there were other disk drives available besides the Epson TF-20

21. References and Further Reading

[1] Epson HX-20 - Technical Manual – Hardware.
[2] Epson HX-20 - Technical Manual – Software.
[3] Eratosthenes Sieve Benchmark Program, BYTE 1/1983.
[4] E. Balkan, "Using and programming the Epson HX-20", Van Nostrand Reinhold, 1985.
[5] http://electrickery.xs4all.nl/comp/hx20/
[6] Brenndörfer, Knut, "Mehr Speicher für den HX-20", Magazin "mc" 4/1984, pp. 119-121.
[7] Jebautzke, Michael, "Drucker am High-Speed Interface", Magazin "mc" 7/1985, pp. 82-83.
[8] Bahmann, Wolfram, "Disassembler für HX-20", Magazin "mc" 7/1983, pp. 66-67.
[9] Rohlfs, Kristen, "HX-20 plottet Funktionen", Magazin "mc" 1/1984, pp. 86-87.
[10] Gründler, Rolf, "Datenbank-Dialog mit dem HX-20", Magazin "mc" 12/1983, pp. 56-58.
[11] Schnieder, Hermann, "HX-20 als Terminal", Magazin "mc" 2/1984, pp. 58-60.
[12] Wald, Elizabeth, "Slipping Sideways", PCN February 1984.