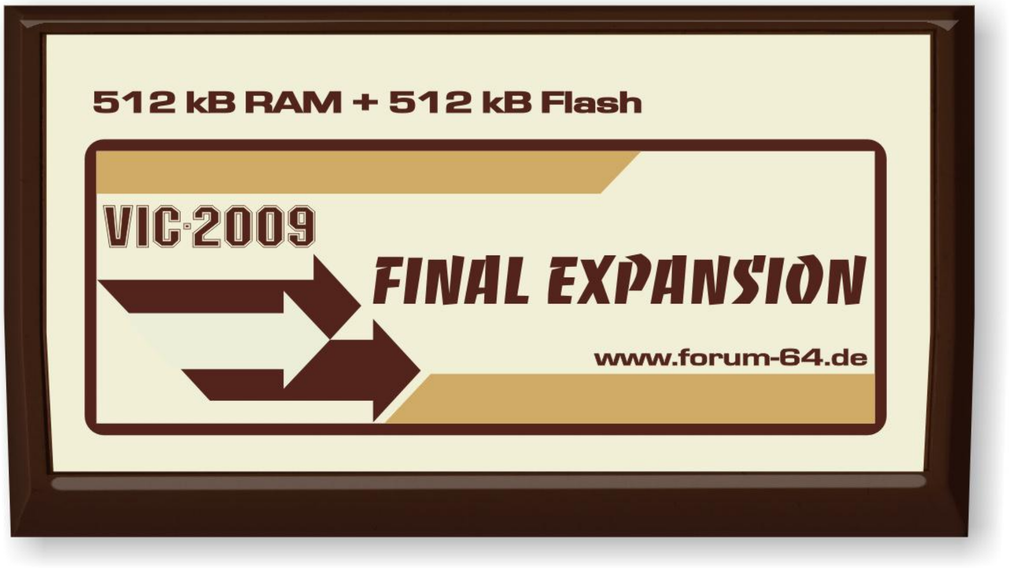
Final Expansion 3 for the VIC-20



- 512 KB SRAM
- 512 KB Flash
- SD2IEC
- Real Time Clock
- Reset button VIC-20 (red)
- Reset button FE3 (blue)

Contents

Features

The VIC-20 Final Expansion is a universal memory expansion for the Commodore VIC-20 home computer. The FE3 is a cartridge for the expansion slot of the VIC-20. The current version v3.2 has following features:

- 512 KB memory expansion of main memory
- 512 KB Flash memory
- SD card as a mass storage device
- RTC (real-time clock) and a connector for an LCD display

The Final Expansion can start any known VIC-20 software. Games and programs will be started by a comfortable menu. The FE gives any expected environment for any software and configures memory requirements automatically on startup.

Hardware

In addition to the SRAM (628512) and flash memory (AM29F040) chips, the PCB contains an Atmel CPLD (ATF-1504) and an Atmel controller (ATmega644 or ATmega1284). The controller is for the µIEC (SD2IEC) functionality. The CPLD controls the logic of the FE3 in a single chip.

Software

The firmware of the FE3 is contained within the flash memory. It starts immediately after power on and when the VIC-20 is being reset. The manual describes all features of the firmware.

The firmware consists of two parts:

- The **menu system** for choosing features of the FE3
- The **FE3 Wedge** extends the command set of the VIC-20 and implements SJLOAD/SJSAVE (Jiffy compatible load and save). Cause the integrated SD2IEC is also Jiffy compatible, it is a benefit also with the disk loader.

The menu system offers the following features:

- **RAM Configuration**: This menu point allows to configure any known memory configuration of the VIC-20.
- **Disk loader**: This menu point exists to load and execute programs on SD card or floppy disk. The disk loader is free configurable by the User and supports any kinds of floppy disk drives and of course the integrated SD2IEC (µIEC).
- **Cart loader**: This menu point exists to load and execute programs directly from flash memory. The flash provides 480KB (from 512KB) user space. You can fill this user space with most favorite games and programs. All kind of programs are possible (BASIC, programs, cartridges) to flash into user space.
- **Utilities**: This are programs to update the firmware and write selected programs and games into the flash memory.

Third party software

- **Task Switcher for FE3**
  A Task Switcher for the Final Expansion 3
  http://sleepingelephant.com/ipw-web/bulletin/bb/viewtopic.php?p=63388#63388

- **RAM Disk for FE3**
  A RAM Disk for the Final Expansion 3
  http://sleepingelephant.com/ipw-web/bulletin/bb/viewtopic.php?t=5342

Reproduction

The schematic of the FE is free available and the firmware is open source. Everyone can build a FE3 themselves easily. It is possible to build a FE3 on a breadboard or a 8-Bit Baby (see also Final Expansion v1).

There are also kits available at http://www.sinchai.de/.

WEB Links

- **FE3-20 available at Retro-Donald**
  http://www.sinchai.de/index.php?main_page=product_info&cPath=1&products_id=77
- **Homepage of the Final Expansion 3 (english)**
  http://t-winkler.net/dokuwiki/doku.php?id=en:fe3:start
- **Homepage of the Final Expansion 3 (german)**
  http://t-winkler.net/dokuwiki/doku.php?id=fe3:start
- **Old Homepage of the Final Expansion (english)**
  http://vc20final.t-winkler.net/index_en_old.html
- **Old Homepage of the Final Expansion (german)**
  http://vc20final.t-winkler.net/index_old.html
- **Forum-64 - Final the fe3 is a teamwork**
  http://www.forum64.de/wbb3/board65-neue-hardware/board284-massenspeicher/board283-vc-20-final-expansion/
- **Forum-64 – development thread**
  http://www.forum64.de/wbb3/board65-neue-hardware/board284-

massenspeicher/board283-vc-20-final-expansion/28606-vc20-neoram-ram-rom-expansion/

- **Source files & Firmware**
  http://vc20final.t-winkler.net/zip/
- **Article **Final Expansion für VC20** in the CeVi-aktuell (Ausgabe 06/2009)**
  http://www.c64-wiki.de/index.php/CeVi-aktuell#CeVi-Aktuell_-_06.2F2009
- **LOADER files (english)**
  http://vc20final.t-winkler.net/docu/loader_e.html
- **LOADER files (german)**
  http://vc20final.t-winkler.net/docu/loader.html
- **technology and programming (english)**
  http://vc20final.t-winkler.net/docu/internals_e.html
- **technology and programming (german)**
  http://vc20final.t-winkler.net/docu/internals.html
- **VC-20 Final Expansion c64-wiki.de**
  http://www.c64-wiki.de/index.php/VC-20_Final_Expansion
- **Final Expansion Rev.9 assembly instructions**
  http://vc20final.t-winkler.net/docu/aufbau/vc20fe3r9_aufbau.htm
- **Final Expansion Rev.9 assembly instructions Forum-64 thread**
  http://www.forum64.de/wbb3/board65-neue-hardware/board284-massenspeicher/board283-vc-20-final-expansion/30960-vc20-final-expansion-aufbau-rev-9/
- **Final Expansion Rev.10 assembly instructions**
  http://www.sinchai.de/index.php?main_page=page&id=10&zenid=402afa75cdfb1eaa0cd5ff0fc57b72af
- **Final Expansion denial wiki**
  http://sleepingelephant.com/denial/wiki/index.php?title=Fe3

Assembling

The Final Expansion 3 is buyable as a kit:
http://www.sinchai.de/index.php?main_page=product_info&cPath=1&products_id=77

All parts must be soldered on the PCB. Look at the Assembly instructions:
http://www.sinchai.de/index.php?main_page=page&id=10

Firmware installation

After assembling the Final Expansion 3 your flash memory is empty and the controller flash also. You need to install the FE3 firmware:
http://vc20final.t-winkler.net/zip/

After assembling the Final Expansion 3 no firmware is installed. Switching on the VIC-20 you will see same as without connected FE3 (normal VIC-20 start message screen). You must install the firmware to support the new hardware.

The FE3 consists of two separate parts, so you will need two different firmware:

- for the FE3 memory expansion
- for the integrated SD2IEC (µIEC-SD)

The firmware for the SD2IEC must be copied simply to the SD card. After power on, the SD2IEC searches for an update file on the SD card and will install it automatically (if current firmware is older).

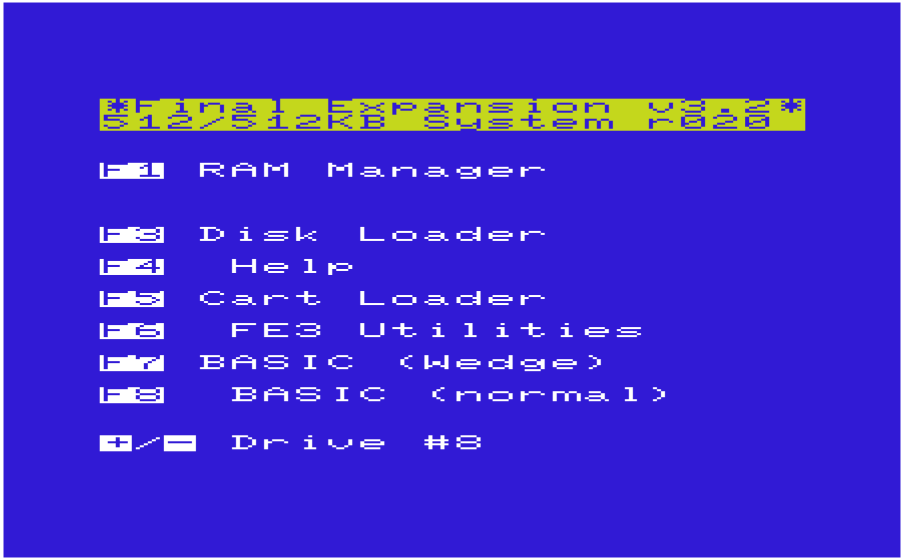
The firmware for the memory expansion will be programmed into the flash memory. For this is the program **FE3FLASH**, which is included in every firmware package.

Caution: The program **FE3FLASH** is necessary only if no firmware is installed or if current firmware doesn't work properly. Otherwise the firmware can update itself using the menu system (see FE3 Utilities, - press key F6 from main menu).

Menu system handling

The FE3 main menu appears after power on your VIC-20 and also after pressing blue reset button. Make sure your FE3 is firmly inserted into the expansion slot of the VIC-20.

If the main menu doesn't appear, maybe the firmware is missing, see also: install firmware.



```
*Final Expansion v3.2*
512/512KB System r020

F1  RAM Manager

F3  Disk Loader
F4   Help
F5  Cart Loader
F6   FE3 Utilities
F7  BASIC (Wedge)
F8   BASIC (normal)

+/-  Drive #8
```

In the main menu we select one of the available features:

F1 RAM Manager: Configures your FE3 as a memory expansion.

F3 Disk Loader: This menu point starts a game or program from internal SD card or a connected floppy.

F4 Help: A help screen appears which explain helpful information for using FE3 outside the menu system.

F5 Cart Loader: This menu point starts a game or program from internal flash memory.

F6 FE3 Utilities: The utility sub menu is for erasing and writing the internal flash memory.

F7 BASIC (Wedge): Starts your VIC into BASIC with enabled (FE3 wedge) and full memory expansion.

F8 BASIC (normal): Starts your VIC into BASIC without FE3 wedge (normal BASIC command set) and full memory expansion.

+/- Drive #8: Changes the default device number for storage devices. Default is 8, normally this is your internal µIEC (SD2IEC) device.

The following keys are also available in the main menu:

D: The “Credits Screen” contain the names of all people who were helpful while developing the FE3 firmware. Thanks to all of you on the list for information, code fragments and other helpful things, it would be more difficult if not impossible without your help.

Pressing the **<CBM>** key (Commodore key) **while reset** (or power on), the VIC-20 will start as without inserted Final Expansion. You will see a normal startup screen, no FE3 wedge and no memory expansion. Internal µIEC (SD2IEC) is available normally if connected to IEC port.

Pressing the **<Shift>** key **while reset** (or power on), the VIC-20 will start without main menu directly into the BASIC v2. The FE3 wedge is active but without memory expansion.

Command set extension (FE3 wedge)

The FE3 wedge extends the command set of the VIC-20.

These additional commands make it easier to use the VIC and storage devices (µIEC and floppy disk). Aside from this FE3 wedge speed up the data transfer to Jiffy compatible storage devices like a µIEC (SD2IEC).

Reset Keys

The FE3 has two integrated reset keys:

- **Blue button** (former red): Big reset, concerns CPLD and VIC-20
- **Red button** (former yellow): Small reset, concerns VIC-20 only

Why two keys? Pressing the blue button the configured memory configuration is lost. So FE3 menu always appears with the blue key, it is like after powering up. Sometimes however we want to keep the memory configuration and want only to reset the VIC-20. This applies to nearly all VIC game and tool cartridges. For emulating cartridges it makes sense to can set a reset without losing the cartridge. So with the red button, the FE3 can act as a real cartridge inserted in your VIC.

The jumper (JP7) controls the reset of the µIEC (SD2IEC) controller. If JP7 is set, SD2IEC makes a reset same time with VIC-20. As default JP7 is open, so µIEC doesn't get a reset. Normally a µIEC never crashes, so a reset is not necessary. After a reset the µIEC loses the current sub directory and current image file, it return to the root directory of the SD card.

FE3 RAM Manager

Memory Expansion

The VIC-20 has in its standard configuration (unexpanded) a small main memory. Only 5KB are free for programs (code) and data. This is the reason why a number of memory expansion cartridges were available soon. Memory was very expensive at this time, so first expansion had only 3KB. But soon there were other memory expansions available with a size of 8KB and 16KB and even more.

The VIC-20 changes the start address for BASIC programs video memory and if memory expansions are active:

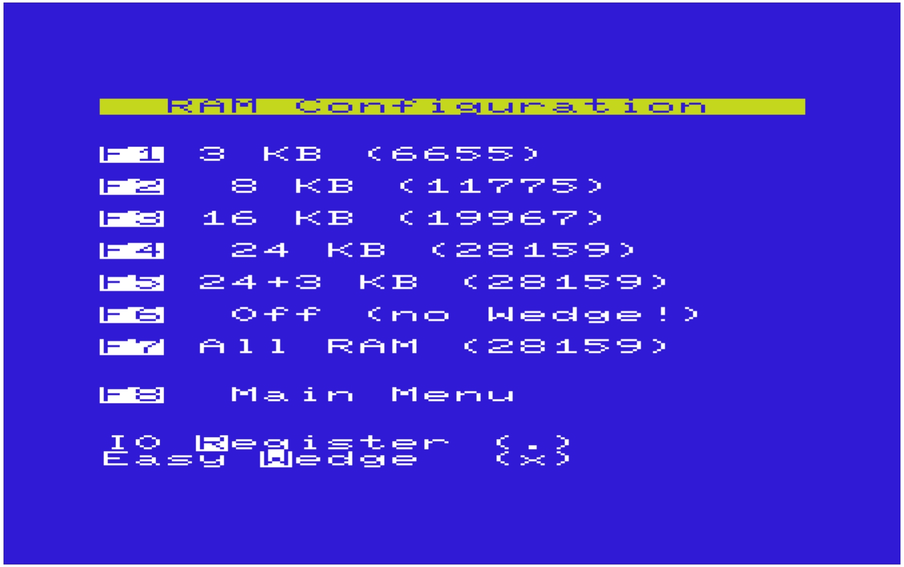
	BASIC Start	Screen RAM	Color RAM	Bytes Free
none	$1001	$1e00	$9600	3583
3KB	$0401	$1e00	$9600	6655
8KB	$1201	$1000	$9400	11775
16KB	$1201	$1000	$9400	19967
24KB	$1201	$1000	$9400	28159

This movement of start addresses many games and programs won't run if a special configuration is missing. So some games only run on an unexpanded VIC-20. Other games only run with 3KB expansion and some other needs an 8KB or 16KB cartridge.

The Final Expansion 3 can be configured (by software) to emulate any combination of memory expansion. So every known game and program can run on a FE3.

RAM Manager

The RAM manager will be started from the main menu of the FE3 firmware by pressing F1.



```
     RAM Configuration

F1  3 KB  (6655)
F2   8 KB  (11775)
F3  16 KB  (19967)
F4   24 KB  (28159)
F5  24+3 KB  (28159)
F6   Off  (no Wedge!)
F7  All RAM  (28159)

F8   Main Menu

 IO Register   (.)
Easy Wedge     (x)
```

All usually needed memory models are available by selcting a menu point. Pressing the corresponding function key will automatically configure the FE3 and start the VIC into BASIC.

Each memory model can be configured by two options:

IO Register … The **<R>** key toggles the IO-register option. If the option is set (X), the software register of the FE3 are visible. If the option is reset (.), the software register of the FE3 are disabled and a reconfiguration is not possible.

FE3 wedge … The **<W>** key toggles the wedge option. If the option is set (X), the command extension (FE3 wedge) is active. If the option is reset (.), the standard BASIC v2 will be started and the additional commands are not available.

The memory models 24K (F4) and 24+3K (F5) have the same start message and same amount of free memory is reported by the BASIC interpreter. The model 24+3 enables the 3K memory expansion in block 0. The BASIC interpreter of the VIC-20 cannot use the 3K expansion if a 8K expansion is active. You can use the 3K expansion for assembler programs or data blocks.

The memory model “All RAM” (F7) uses all blocks for RAM expansion including block 5. The BASIC interpreter only can use 24K of memory expansion, the 3K RAM in block 0 and the 8K RAM in block 5 are free for own code or data.

The memory model “Off” (F6) disables all memory expansions, the VIC-20 starts unexpanded as without FE3 inserted. All programs and games which are designed to run on a unexpanded VIC will run fine in this mode. Cause no memory is available for FE3 wedge, the wedge is disabled even the option is on and your VIC starts with standard BASIC.

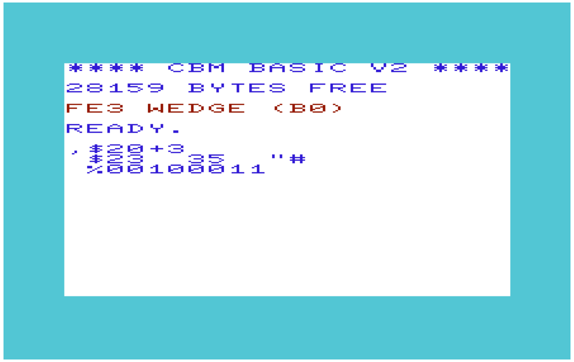
FE3 Wedge in LoMem

The memory model “All RAM” (F7) fills all blocks with RAM (maximal expansion). This memory model normally is chosen because the user want do something with block 5. The FE3 firmware and also the FE3 wedge normally run in block 5. So FE3 wedge is moved to block 0 (low memory) in this memory model.

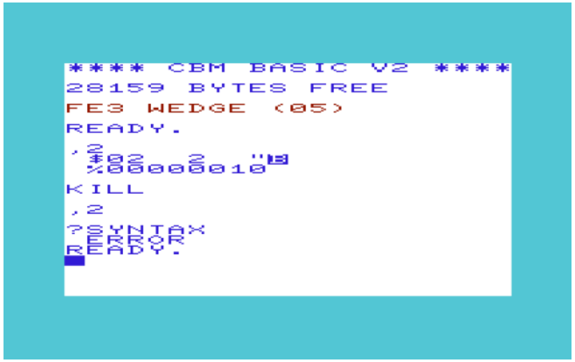
In block 0 is only 3KB available, so the FE3 wedge has a limited command set. Beware, block 0 is not protected and could be overwritten. Caution: be careful with writing to memory (POKE), don't bite the hand that feeds you … ;-)

Of course you could disable FE3 wedge using the option or disable it after starting BASIC with the wedge command KILL or OFF.

The start message shows the start address of the FE3 wedge. The red message of the wedge shows the address in parentheses. If a “B” is listed the wedge run in block 5, a 05 indicates a address in block 0:



```
**** CBM BASIC V2 ****
28159 BYTES FREE
FE3 WEDGE (B0)
READY.
,$20+3
 $23    35   "#
 %00100011
```



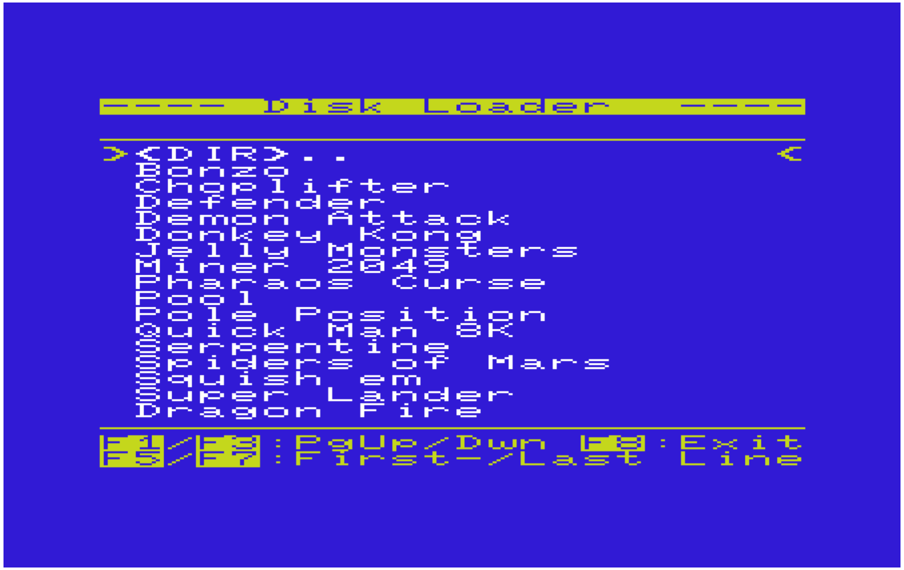
```
**** CBM BASIC V2 ****
28159 BYTES FREE
FE3 WEDGE (05)
READY.
,2
 $02    2   "
 %00000010
KILL
,2
?SYNTAX
 ERROR
READY.
```

FE3 Disk Loader

The disk loader will be started from main menu with the <F3> key. With this disk loader you can start pre configured games and programs very comfortable and easy.

Start programs

Choose from the list of games and programs and select it using cursor keys or joystick. The <Return> key (or fire on the stick) will start the game/program.



```
---- Disk Loader     ----

><DIR>..                 <
 Bonzo
 Choplifter
 Defender
 Demon Attack
 Donkey Kong
 Jelly Monsters
 Miner 2049
 Pharaos Curse
 Pool
 Pole Position
 Quick Man 8K
 Serpentine
 Spiders of Mars
 Squish em
 Super Lander
 Dragon Fire

F1/F3:PgUp/Dwn F8:Exit
F5/F7:First-/Last Line
```

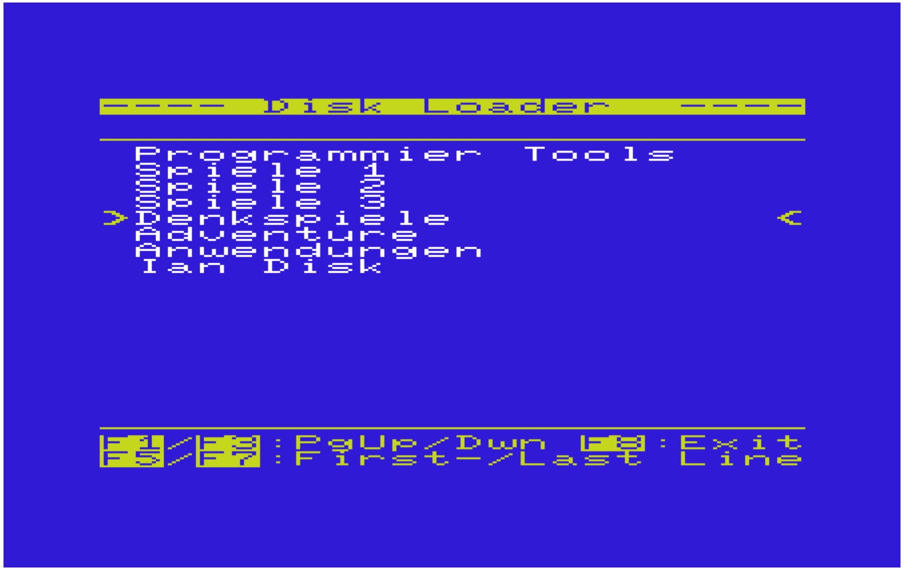
If more than 17 menu entries are available, you can change the page using <F1> and <F3> keys. The keys <F5> and <F7> selects the first or last entry of the page. This makes it possible to navigate very fast within the menu.

Change a Disk Image

You can organize your games and programs on the SD card in subdirectories, image files (D64, D71, D81, DNP) or M2I files. The image files are my most favorite method cause this solution is the nearest to real diskettes and very compatible.

To change into a subdirectory or an image file you can use the disk command **CD:**. To leave a subdirectory or an image file you can use **CD:**←. This disk command (and any other disk command) can be behind a menu entry of the disk loader. The first menu entry on the screenshot above shows **<DIR>..**, this entry bring you back to the root of the SD card, back to the image file selection. Behind this menu entry is simply the disk command **CD:**←.

The menu structure of the disk loader is free configurable. I have my most important programs packed into some image files (D64 files). Each disk loader menu comes from a (**LOADER** file). The first page loaded by the disk loader is the LOADER file in the root of the SD card, it contains links to subdirectories and/or D64 image files. Behind each of this menu entries to select a image file or subdirectory is a simple **CD:** command for the SD2IEC:



```
-----  Disk Loader   -----

  Programmier Tools
  Spiele 1
  Spiele 2
  Spiele 3
>Denkspiele                   <
  Adventure
  Anwendungen
  Ian Disk

F1/F3:PgUp/Dwn F8:Exit
F5/F7:First-/Last Line
```

Disk loader Configuration

The Disk loader is free configurable. For this we use (LOADER files). These LOADER files are simple files with filename "**LOADER**" and same structure as normal BASIC program files.

Since LOADER files are similar to BASIC programs, we can do the same well known procedures like LOAD, SAVE and LIST. We can edit LOADER files like normal BASIC programs, first LIST the code and edit directly on the screen, exactly as we would do with BASIC code. We need no utility, all editing can be made by VIC-20 standard methods.

A LOADER file contains a whole menu list for the disk loader, all entries in one file, one or more pages. When the disk loader is started, it loads the LOADER file from current drive into memory and lists the first 17 entries. The LOADER file contains one chapter for each menu entry. Each chapter contains the entry name listed in disk loader menu and one or more commands for this menu entry. This commands can be load, configure and execute commands. Or it can be disk commands like CD: to change into another disk image.

Everyone can make his own set of LOADER files, all connected together for navigation between image files, to get a big collection of games and programs.

How to create LOADER files and which options are possible is documented at the section LOADER files.

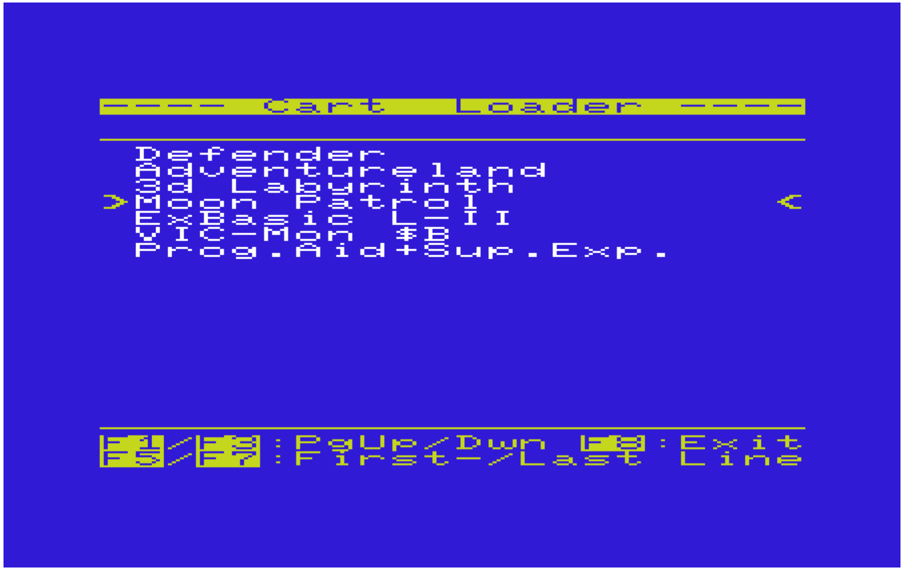
FE3 Cart Loader

The cart loader will be started from the main menu with the <F5> key. With the Cart loader you can start games and programs stored in the flash memory of the Final Expansion.

The idea of the cart loader is, to have all most favorite games and programs in one list and start it easily and quick.

Start programs

Choose from the list of games/programs by using the cursor keys or the joystick. By pressing the <Return> key the game/program will be started.



```
----- Cart Loader -----

   Defender
   Adventureland
   3d Labyrinth
>  Moon Patrol                        <
   ExBasic L-I I
   VIC-Mon $B
   Prog.Aid+Sup.Exp.


F1/F3:PgUp/Dwn F8:Exit
F5/F7:First-/Last Line
```

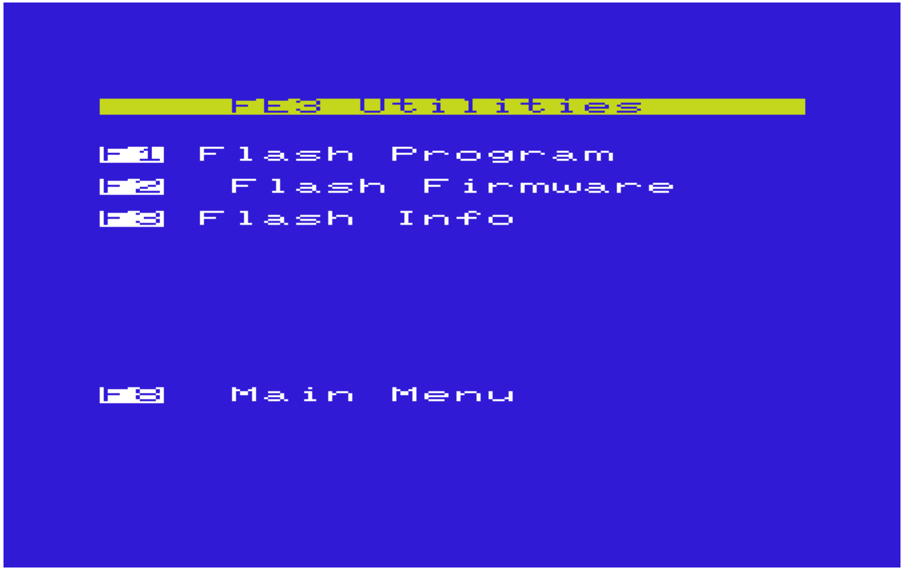
If more than 17 menu entries available, you can switch between pages using the <F1> and <F3> keys. The keys <F5> and <F7> set the selection bar to first and last entry of the page. This is for fast navigation in the cart loader menu.

Add entries to Cart Loader

The cart loader menu can be configured by adding games and programs to the flash. The size of flash memory is 512KB, it can be used 480KB for the cart loader. The remaining memory of 32K is reserved for the firmware.

To add programs to the cart loader menu, the program must be already configured in the disk loader. If this program works fine in disk loader, it will work also fine in the cart loader. But only if this program doesn't access files. The reason is, cart loader doesn't change into any disk image or sub directory.

You can add programs to the cart loader menu from FE3 Utilities menu, this menu is available from main menu. The utility menu has a menu point **F1 … Flash Program**:



Delete Cart Loader entries

The 512KB big flash memory of the FE3 is writable byte for byte. But deleting is only possible in big blocks. This is why flash memory can only deleted completely, single entries cannot deleted.

The cart loader menu is deleted by firmware update.

FE3 Utilities

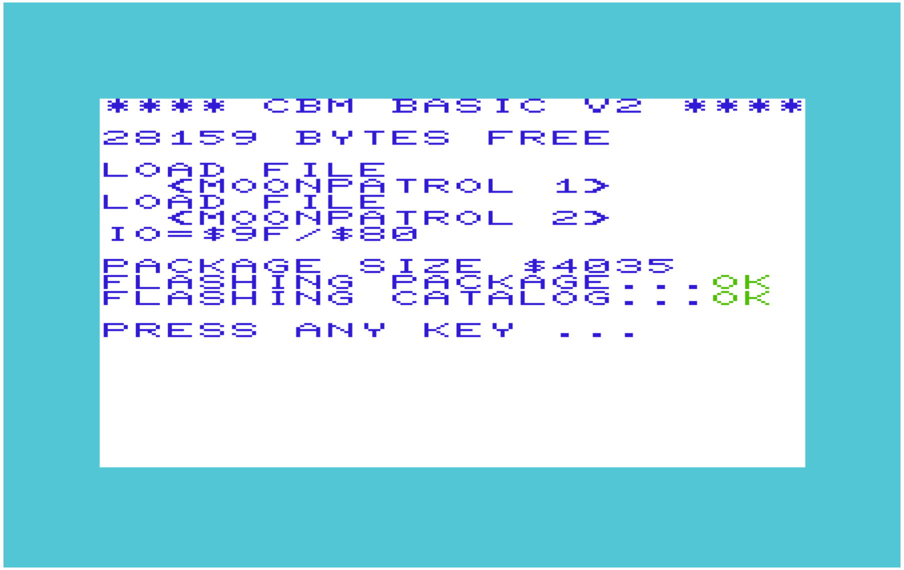
The menu Utilities is for writing the flash memory of the FE3. You can reach this menu from main menu by pressing F6. It includes 3 menu points:

- Flash Program
- Flash Firmware
- Flash Info

Flash Program

This menu point writes games and programs into the flash memory of the FE3. The games and programs must be already configured properly in the disk loader. You will see the same list as in the disk Loader. The difference is you don't start this program but write it into the flash.

If all running fine you will see a screen like this:



```
**** CBM BASIC V2 ****
28159 BYTES FREE
LOAD FILE
    <MOONPATROL 1>
LOAD FILE
    <MOONPATROL 2>
 IO=$9F/$80
PACKAGE SIZE $4035
FLASHING PACKAGE...:OK
FLASHING CATALOG...:OK
PRESS ANY KEY ...
```

After flashing is completed without error you can select and start this program now from the cart loader.

Flash Firmware

Use this menu point to update the (Firmware) of the Final Expansion. This doesn't concern the SD2IEC firmware.

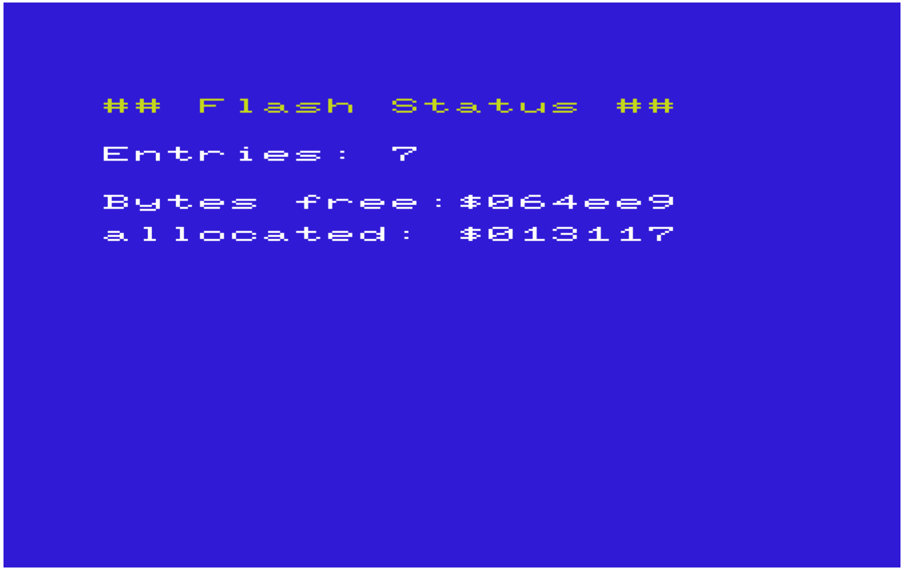
For this you have to copy the new firmware file to the root directory of the SD card. The filename of the new firmware always must be fe3firmware or fe3firmware.prg. After the firmware update a reset is triggered and it should appear the main menu.

Annotation: It must be already installed a properly working firmware to do the update in this manner. If no firmware is installed (or not properly working …), for example after assembling the FE3, the firmware must be written by the program fe3flash. See also Firmware Installation.

Caution: The firmware update erases the whole flash memory! All programs and games in the flash memory are lost and you have to reinstall it again. If a problem occur while firmware update, the FE3 maybe won't start normally (no main menu appears). In this case you have to install the firmware by the utility program fe3flash.

Flash Info

The Flash Info screen informs you about the allocation of the flash memory:



```
## Flash Status ##

Entries: 7

Bytes free:$064ee9
allocated: $013117
```

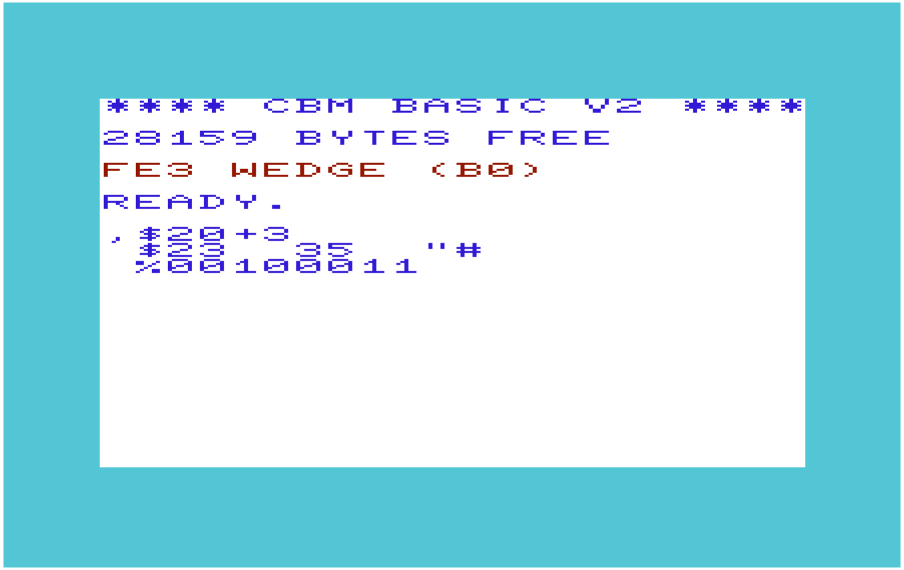
This information is useful to see how much memory is free. So you can estimate how many programs fit in the flash memory.

FE3 Wedge

Functional range

The FE3 Wedge offers this features:

- Extends the command set of the VIC-20
- Arithmetic expressions can include binary and hexadecimal numbers
- Floppy Speeder (SD card and Jiffy Floppy)
- Movable into low memory



```
**** CBM BASIC V2 ****
28159 BYTES FREE
FE3 WEDGE (B0)
READY.
,$20+3
 $23  35  "#
 %00100011
```

Floppy commands

For easy file management new commands are available (one letter shortcuts).

The argument for the shortcuts (filename) can be used either quoted or stand alone.

If a quote sign is on the 4 column (usually for a directory entry), all characters before are ignored. This has a reason: It is for easy using directory entries as an argument, without needs to delete a char. For example you list a directory using the shortcut $, after this you move the cursor up to the file you want, now you can load this file simply by writing the shortcut / and <enter> key …

$..............	The dollar sign lists the directory of the selected drive, without overwriting the program in memory. Letters after the $ selects files with filenames starting with this letters.
@	The “at” sign sends a command directly to the floppy drive (eg: S:, N:, I: …). Without an argument the floppy status is read and displayed.
#..............	With this shortcut the actual device number is set or displayed. Allowed device numbers are 8 to 15. Standard value is 8.
/...............	Shortcut for LOAD. It loads a file with SA=0, this is for BASIC programs.
%.............	Shortcut for LOAD. It loads a file with SA=1, this is for programs at start address in the file. If a start address is entered after the second quote sign, a cartridge file will be loaded (SA=2). Cartridge files doesn't have a start address in the file.

←............. The <left arrow> is a shortcut for SAVE. Optionally a start- and end address can be entered. If the file already exists on the disk, the wedge ask what to do, - replace or update. On “update” always two versions of the file are saved. The older version of the file has a filename prefix, the ' character is used to mark the older file version.

>............... Shortcut for the VERIFY command. The file will be compared with the memory, if same a “OK” is displayed otherwise a VERIFY ERROR appears.

Other commands

These commands are available only in direct mode, not in RUN mode within a BASIC code. The commands can be entered in short form like all other commands by entering the last letter shifted.

,................... The comma is a command for number conversion (mini calculator). All arguments are seen as a numeric expression and calculated. The result will be displayed in different notations: decimal, hexadecimal, binary and as an ASCII string

RESET........ It is like a real VIC reset (red reset key). Other than a SYS64802 it emulates a real reset necessary for some games (mostly cartridge games in block 5) to run properly.

BLK .... This command makes the same as BLKP. it is only for compatibility reasons.

BLKP	This command protects memory blocks against writing. After a program is loaded in a block sometimes it is useful to protect it. Protected blocks seems to be a ROM, the content is read only, writing is ignored. After the BLKP command one or more numbers are entered separated by commas. Possible values are 0, 1, 2, 3 or 5 (block numbers).
BLKD	This command disables one or more memory blocks. The disabled blocks are physically removed, like not existent. Disabled blocks can be used by other cartridges. After the BLKD command one or more numbers are entered separated by commas. Possible values are 0, 1, 2, 3 or 5 (block numbers).
NOIO	The NOIO command disables the 2 software register within the CPLD (address 39938 and 39939) of the FE3. After this are configuration of the FE3 is no longer possible. You can use this for programs which won't run, cause it writes into this register addresses. The FE3 register are available until a hard reset of the CPLD occurs (red reset key).
OFF	Switch off the FE3 Wedge. All vectors are restored. The memory space of the Wedge is free again.
KILL	Exactly the same as OFF
UNNEW	After a NEW command or a VIC reset, BASIC programs seems to be deleted. This command restores the program in memory.
OLD	Exactly the same as UNNEW.
RENUM	will be implemented with release r021
FIND	will be implemented with release r021
DEL	will be implemented with release r021

LOAD and SAVE

Beside the accelerated access to files the FE3 has more benefits:

- Display of start- and end address while loading and saving
- Loading of files without start address (cartridge files) by entering a SA=2
- Loading of files with a given start address by using a SA=1 and a additional argument (start address)
- Saving of files with a given start- and end address

Examples:

```
LOAD “CARTIDGE”,8,2,$A000
LOAD “CARTRIDGE”,8,1,$2000
SAVE “CARTRIDGE”,8,1,$2000,$4000
```

Formula evaluation

The formula evaluation is extended (also within running BASIC programs) by binary and hexadecimal numbers. This can be used everywhere, even for assignments, PRINT commands or any parameters for commands. The different numerations can be used mixed in any combination.

Hexadecimal numbers are preceded by a dollar sign ($). The numbers must have 2 or 4 digits. Only integers are allowed. Usable digits are 0 to 9 and A to F.

Binary numbers are preceded by a percent sign (%). The numbers must have 4, 8, 12 or 16 digits. Only integers are allowed. Usable digits are 0 and 1.

Examples:

```
A = 7 + $2C * 9
PRINT $2F - 14
POKE $A077,$5A
```

Floppy speeder

The accelerated access to files is made by Jiffy compatible procedures (SJLOAD). Jiffy DOS is the most favored serial speeder. LOAD and SAVE are speeded up by 6 to 10 times to normal IEC procedures. The SD2IEC is much faster than a normal Jiffy floppy especially for small files. The reason is SD card doesn't have a motor startup delay and also no sector search delay.

	normal 1541	Jiffy 1541	SD2IEC
LOAD 48 blocks	21,8s	6,5s	2,2s
SAVE 48 blocks	26,4s	16,1s	7,5s

But not only LOAD and SAVE are sped up by the FE3 wedge, all data access is accelerated if the kernel jmp table is used. This is cause FE3 wedge changes all of IEC concerning vectors of the VIC-20: CHKIN,CKOUT,BSOUT,BASIN,CLALL,CLRCH

The speeder works with all Jiffy compatible floppy drives, including the internal µIEC (SD2IEC). Normal floppy drives (not Jiffy powered) run fine but only with normal (slow) speed.

If the wedge is running in low memory (block 0), floppy speeder is disabled. This small version of the FE3 wedge doesn't have this feature, because only 3K RAM is available.

Movable into low Mem

The FE3 Wedge normally uses an address range at $B (upper side of block 5). Block 5 cannot used by BASIC v2, so this is a good location for the wedge.

By choosing full RAM in the RAM manager (F1, F7) whole block 5 will be usable RAM. In this case a small version of the FE3 wedge is copied into the low memory (3K expansion area at block 0). This version of the wedge has a limited command set, cause limited space in block 0.

LOADER files

The purpose of the Loader files:

The loader file is needed by FE3 Disk Loader which is always looking for the file "LOADER" in the current directory. Disk Loader interprets these script files saved in the form of VIC Basic prg files but not actually executable Basic Programs.

Using these scripts you can select and easily start any games and / or programs with no programming skills - once you have set them up or downloaded them ;-)

Once the FE3 Disk Loader can load a program it can also be added to the FE3 Flash Rom. The Cart Utilities (F6) Flash Program (F3) makes use of the Loader scripts to package the files and commands into an executable block of code before flashing to the rom.

Structure of the file "LOADER"

The LOADER file consists of one or several sections. Each section is presented as a menu item in Disk loader. A section consists of:

- a **name**: each section begins with a name in the menu displayed in Disk loader
- one or more **instructions**
- **comment lines** may be added optionally

- **names** begin and end with a **quotation mark (")**
- **Instruction** lines always begin with a **plus sign (+)**
- **comment** lines begin with a **colon (:)**

The section name will begin and end simply with a quotation mark ("). The name can be up to 20 characters and may include any special characters. If the name is longer than 20 characters, Disk loader shows only the first 20. Control characters are ignored.

The instructions in a section are performed when the user activates the menu item in Disk Loader by pressing the RETURN key or the joystick FIRE button. Instruction lines always begin with a plus sign (+).

The sequence of instructions will be chosen by Disk Loader as follows:

Disk loader always executes:

- first **LOAD** instructions,
- then **BLK** and **IO** instructions, and
- last **RUN**, **SYS** or **RESET** commands.

The order in the script is only relevant for commands of the same sub type e.g. multiple LOAD commands.

The optional comment lines begin with a colon (:). The comment line can be blank (Section divider) or contain any text strings. A comment line does not end the section. Comment lines are optional and can therefore be omitted entirely.

A section ends with the end of the script file or the beginning of a new section.

Instructions

The following statements are recognized by Disk loader and interpreted:

- **Load statement** : Loads a file from a floppy disk or SD
- **Disk Command** : Sends a command to the SD2IEC or to a floppy.

- **BLK, BLKP, BLKD** : Instructions for configuring the FE3 hardware - block write protect or disable.
- **NOIO** : Instructions for configuring the hardware FE3 – Hide FE3 IO registers.
- **RESET** : Instruction to restart the VIC-20 (Soft Reset)
- **SYS** : Starts a machine code program at the given address (in hexadecimal!)
- **RUN** : Starts a BASIC program
- **RELOAD** : Restart command to the File Loader (runs the Loader script in the current directory)

The **Load Statement** loads a file from the SD card or from a floppy. Several load instructions can be sequenced if for example games with several parts exist. In the simplest case the statement can consist of only one file name. The file name consists of up to 16 characters and is enclosed in quotation marks.

An optional type can be specified and appended to the load command.

File types are **B (BASIC)**, **P (PROGRAM)** and **C (cartridge)**. These correspond to the secondary address (0,1,2) of the modified LOAD command in FE3 Wedge.

The file type **BASIC** is automatically always loaded at the address where the BASIC memory starts (secondary address 0). This address may vary depending on memory configuration.

The file type **PROGRAM** is always loaded at the address that is contained in the file (the first two bytes). This corresponds to a LOAD with secondary address 1. The load address can optionally be overridden - See - optional load address.

The file type **CARTRIDGE** is for files without a load address. These files are often recognized by the exact file size of 4K (4096), 8K (8192) or 16K (16384). This file type requires always an indication of the load address!

The load statement may also have an optional load address appended. For file type C, the load address is always required. The **load address** must always be **hexadecimal**, starting with a **$** sign.

The load commands are executed in the order given. If you intend to load something into the cassette buffer from $330 onwards, this must be the last section! This is because the Disk Loader uses this area of memory.

Examples of load commands:

```
+"MOONPATROL"
+"EXBASIC2",C,$A000
+"AUSTRO COMP",B
+"VICMON",P,$3000
```

A **Disk Command** starts with the **AT sign (@)** followed by the actual command in quotes. You can send any possible commands to the target device (SD2IEC or floppy) provided the device understands the command.

The main application of the Disk Command may be to change the current directory or the current disk image (D64). We can comfortably navigate the SD card this way. You do not have to have all the games in a single huge list, it can be arranged as you wish.

As stated any disk command is possible. You can for example erase a high score table with an "S" command or a high score table could be saved by the C (Copy) or R (Rename). This is limited only by your imagination.

Disk Commands can be used before or after a Load command.

The configuration of the FE3 is only necessary for the specific games and programs. If a game or program runs without running a configuration you can do without these instructions.

There are games and programs that do not run by normal load and start. The program does not find the necessary environment and can / will therefore not run. By configuring the hardware, FE3 can simulate every possible memory expansion hardware and run every known program except for those which require very specific hardware modules e.g. 80 character card, IEEE-488 card, RS-232/Modem cards etc.

The commands BLK, BLKD and BLKP configure the memory. The block numbers can follow the command in any order: 0,1,2,3,5. All five memory blocks are enabled by default and must be turned off to get smaller or unexpanded memory configurations.

The block numbers correspond to the physical blocks of the VIC-20:

- **0** = Block 0 ($ 0400 - $ 0FFF)
- **1** = Block 1 ($ 2000 - $ 3FFF)
- **2** = Block 2 ($ 4000 - $ 5FFF)
- **3** = Block 3 ($ 6000 - $ 7FFF)
- **5** = Block 5 ($ A000 - $ BFFF)

The blocks can be disabled and protected against overwrite individually:

- **BLKD** disable Block
- **BLKP** protect Block (BLK is equal to BLKP for backward compatibility)

Inactive blocks are quasi-nonexistent. The FE3 acts like it is not populated in the corresponding range of addresses. Another cartridge could be used with FE3 in a multi slot expansion in the address blocks that have been disabled.

Blocks with write protection act like a ROM or EPROM. These blocks can only be read from, write commands are ignored.

The command **NOIO** hides the registers of FE3. After this is set, further configuration of the FE3 is no longer possible and the corresponding IO area is free. A hardware reset puts the FE3 back to the original state and allows reconfiguration.

Examples of configurations:

```
+BLK 1,3
+BLKD 0,1,2,3
+BLKP 0,1,2,3,5
+NOIO
```

Loaded games or programs must be started, the commands **RESET**, **RUN** and **SYS** are available to do this. One of the three commands is used depending on the requirements of the program.

After the Disk Command to change the directory or the disk image, the command **RELOAD** must be used. In the new directory or the new D64 Image has to be another LOADER file that must be loaded by the Disk Loader.

Without the RELOAD command the Disk Loader works with the wrong file and thus the wrong LOADER instructions. The statements cannot be executed because for example, the file to load is no longer accessible in the directory.

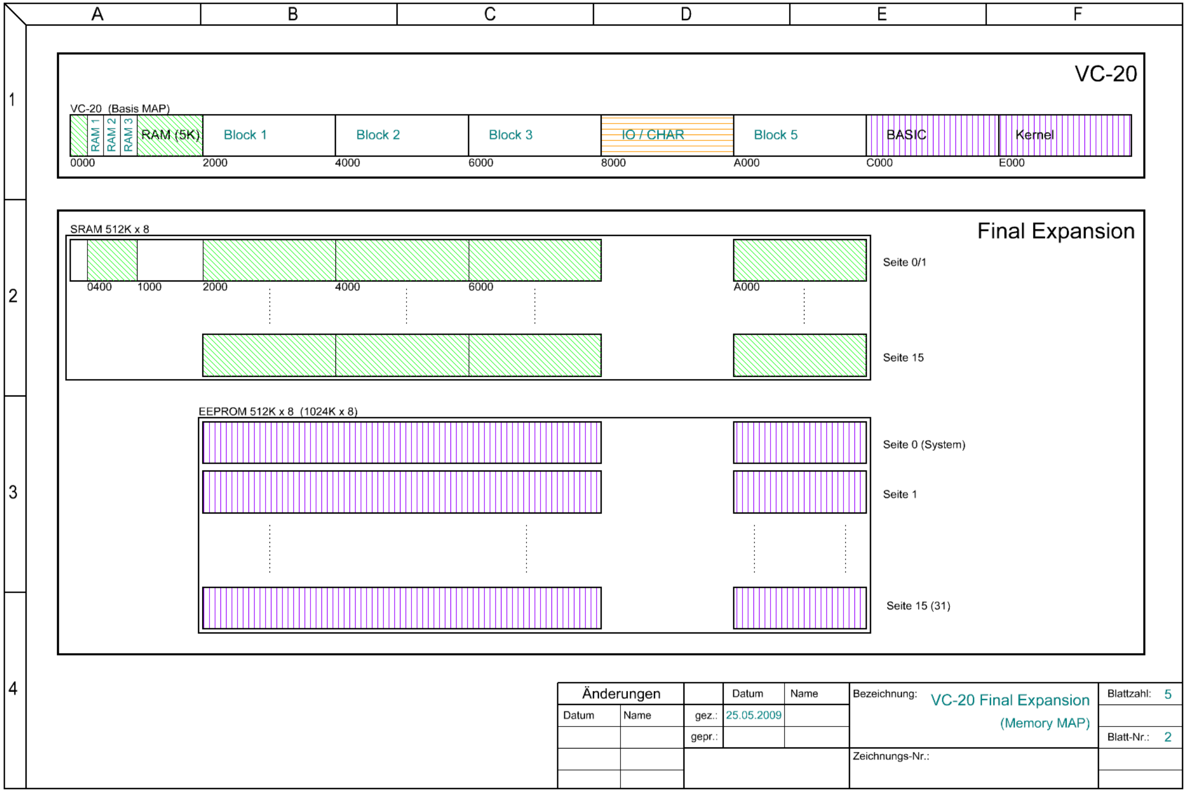
Example 1 of a LOADER file:

```
10 "HW Demo unexpanded"
20 +"hello world",b
30 +blk 0,1,2,3,5
40 +run
50 :
60 "HW Demo 3K"
70 +"hello world",b
80 +blk 1,2,3,5
90 +run
100 :
110 "HW Demo 8K"
120 +"hello world",b
130 +blk 0,2,3,5
140 +run
150 :
160 "HW Demo 16K"
```

```
170 +"hello world",b
180 +blk 0,3,5
190 +run
200 :
210 "HW Demo 24K +8 +3"
220 +"hello world",b
230 : no blk command
240 +run
250 :
```

FE3 technology and programming

The Final Expansion contains 512KB SRAM and 512KB Flash memory. In order to access the expanded memory one has to enable it sequentially. This is due to the constraints of the address range of the 6502 processor which can only see 64KB at a time. On the VIC-20 the free address space is constrained to 4 x 8KB + 3KB (See memory map):


A
B
C
D
E
F
1
2
3
4
VC-20
VC-20 (Basis MAP)
RAM 1
RAM 2
RAM 3
RAM (5K)
Block 1
Block 2
Block 3
IO / CHAR
Block 5
BASIC
Kernel
0000
2000
4000
6000
8000
A000
C000
E000
Final Expansion
SRAM 512K x 8
0400
1000
2000
4000
6000
A000
Seite 0/1
Seite 15
EEPROM 512K x 8 (1024K x 8)
Seite 0 (System)
Seite 1
Seite 15 (31)
Änderungen
Datum
Name
Datum
Name
gez.:
25.05.2009
gepr.:
Bezeichnung:
VC-20 Final Expansion
(Memory MAP)
Blattzahl: 5
Blatt-Nr.: 2
Zeichnungs-Nr.:

Registers:

The Final Expansion has 2 registers in order to configure it through software. The registers are accessed like memory addresses and can be read from (PEEKed) and written too (POKEed). The registers have 8 bits as for other memory addresses. After a Hard Reset or after switching on the VIC-20, both registers contain Zero.

Register 1 39938 ($9C02):

With Register 1 the **MODE** of the Final Expansion can be selected. The Register is located at address 39938 ($9c02).

Values are written to the register With POKE 39938,x. Values are read from the Register with PEEK(39938).

The highest 3 bits (Bit 5,6 and 7) control the usage mode of the Final Expansion. The lowest 5 bits (Bit 0,1,2,3 and 4) provide additional information the selected mode of use. It is possible to build a value for the register using AND and OR logic and then poke the resulting number to the Register. (Register 1: MMMIIIII).

M - Mode of Use

I - Additional Information

Register 2 39939 ($9C03):

With register 2 the **RESOURCES** of Final Expansion can be enabled or disabled. The Register is located at 39939 ($9c03). Values are written to the register With POKE 39939,Y. Values are read from the Register with PEEK(39939).

The VIC-20 has 5 free address ranges (memory blocks). The Final expansion can make these 5 blocks available independently. This means the Final Expansion memory can be made available in one or more blocks to the VIC-20 (Banking)

The lower 5 bits (Bit 0,1,2,3 and 4) of Register 2 control the visibility of the 5 memory blocks in the VIC-20. A 0 switches the relevant block on and a 1 switches it off. The configuration of individual blocks is needed to enable compatibility with other expansion modules.

The highest bit (Bit 7) of Register 2 controls the visibility of the Registers themselves. A 0 makes the Registers visible, a 1 hides the Registers (Deactivates the Registers)

ATTENTION: if the Registers are deactivated then it is no longer possible for the software to alter the memory configuration. Only after a Reset will the Register become visible again.

Disabling these Registers is used to prevent new software from altering the configuration of the Final Expansion without intention. With this facility the compatibility of the Final Expansion with any conceivable software is ensured.

Bit 0 ... Visibility of the VIC-20 memory block 0 (Blk0 - $0400-$0FFF)
Bit 1 ... Visibility of the VIC-20 memory block 1 (Blk1 - $2000-$3FFF)
Bit 2 ... Visibility of the VIC-20 memory block 2 (Blk2 - $4000-$5FFF)

Bit 3 ... Visibility of the VIC-20 memory block 3 (Blk3 - $6000-$7FFF)
Bit 4 ... Visibility of the VIC-20 memory block 5 (Blk5 - $A000-$BFFF)
Bit 5 ... 1: invert A13
Bit 6 ... 1: invert A14
Bit 7 ... Visibility of IO-3 (Register 1 und 2)

Banking:

In order to access the full memory of the Final Expansion, the memory must be switched on in stages. In order to achieve this, a number of modes are available for use in order to cover every requirement.

Final Expansion Modes of use:

START MODE (000zzzzz):

After a reset with the red button or after initial power on, all the bits in the register are set to zero, in this way the FE is always in START MODE after a reset With POKE 39938,0 the START MODE can be activated from software.

Write operations to the FE memory go to RAM in Bank 1.

The 0 Block of the VIC-20 (3k expansion) is disabled.

The START MODE of Final Expansion is provided for maximum compatibility with other modules. In order to avoid possible incompatibility with other expansion modules, The Final Expansion controls only Block 5 (Memory range $A000 - $BFFF). Block 5 must be active, otherwise the firmware of the Final Expansion itself cannot be automatically started.

Because the Final Expansion in START MODE only uses block 5, one can simply deactivate the FE by disconnecting the BLK5 circuit path. (e.g. with a switch). N.B. This would require a modification to the Final Expansion or the VIC-20 expansion port.

The registers are deactivated in START MODE, the Lockbit serves as a control for this.

The lockbit functions only in START MODE in order to avoid incompatibility with other modules that may use the same addresses as Final Expansion for registers.

The lockbit can be cleared via a POKE to Block 5. A PEEK resets the lockbit again.

This way programs in Block 5 cannot write to an FE register as long as the FE is in START MODE.

In START MODE only block 5 is controlled.

Read operations are from the Flash at address $6000 (Flash Block 3, highest block of the first 32k bank - Bank 0).

Write operations always go to SRAM. This way the whole firmware can be simply copied to SRAM.

Write operations to Block 5 go to SRAM address $E000 (SRAM Block 7, highest block of the second 32k bank - Bank 1).

If the SRAM 1 mode is switched to, the SRAM Block 7 lies exactly in Block 5 of the VIC-20.

SUPER ROM MODE (010zzzzz):

With Poke 39938,64 the flash memory of the Final Expansion is enabled.

Read operations come from the ROM (Flash) i.e. from the selected Bank.

Write operations go to the RAM in Bank 1.

The Block 0 of the VIC-20 (3k expansion) is enabled.

The 512KB of the Flash are divided into 16 pages of 32KB, any one of which can be selected for access. These 32KB are further divided into 8KB pieces and are assigned to the addresses $2000 (BLK 1), $4000 (BLK 2), $6000 (BLK 3) and $A000 (BLK 5).

The additional information in the Register (zzzzz) select the relevant 32KB block of the Flash memory,

In 512KB there are 16 x 32KB pages. The additional register values can therefore take the values 0 to 15.

Readers will notice that the additional register information can hold 5 bits or 32 values.

Correct, the Final Expansion can also address 1MB chips. However, these are not available to buy in DIL packages, therefore this cannot be used.

RAM 1 MODE (100zzzzz):

With POKE 39938,128 the SRAM of the Final Expansion is activated.

Read operations are always from RAM Bank 1.

Write operations go to RAM Bank 1 or optionally to Bank 2.

The Block 0 of the VIC-20 (3K Expansion) is switched on. The Bit 0 of Register 1 controls the write protection. There is up to 35KB of SRAM available to configure (4 x 8KB + 3KB) at the addresses $0400 (BLK 0), $2000 (BLK 1), $4000 (BLK 2), $6000 (BLK 3) and $A000 (BLK 5). The 3KB expansion (VIC-20 BLK 0) comes from Bank 0 (The first 32KB in SRAM) of the SRAM. The four 8KB blocks in the VIC-20 (BLK 1 - BLK 5) come from Bank 1 (The second

32KB in SRAM) of the SRAM. This way all the addressable space in the VIC-20 is filled with RAM and therefore the maximum expansion with memory is achieved.

The additional information bits in Register 1 (zzzzz) control the write access to the RAM blocks. Bit 4 controls BLK 5, Bit 3 Controls BLK 3, Bit 2 Controls BLK 2, Bit 1 Controls BLK 1 and Bit 0 Controls BLK 0. If the Bit is set to 0 then the RAM Block 0 can only be read not written. (1: write protection = on??? Off??? The bits for Blocks 1 to 5 control the target for the write operation. If the bit is not set (0) then the write operation is to Bank 1 of the RAM. If the Bit is set to (1) then the write operation is to Bank 2 of the RAM.

Changing the target for the write operation functions as a kind of write protection. A write protection is needed in order to emulate a ROM cartridge. First one writes the ROM content to RAM and then one protects it from being overwritten.

Why do we need this? Some game cartridges overwrite themselves (intentionally), so that they won't run in RAM.

RAM 2 MODE (110zzzzz):

With POKE 39938,192 RAM Mode 2 of the Final Expansion is activated.

Read operations come from the RAM Bank 1 or optionally from Bank 2.

Write operations are always to RAM Bank 1.

The Block 0 of the VIC-20 (3K Expansion) is switched on. The Bit 0 of Register 1 controls the write protection. There is up to 35KB of SRAM available to configure (4 x 8KB + 3KB) at the addresses $0400 (BLK 0), $2000 (BLK 1), $4000 (BLK 2), $6000 (BLK 3) and $A000 (BLK 5).

The 3KB expansion (VIC-20 BLK 0) comes from Bank 0 (The first 32KB in SRAM) of the SRAM.

The four 8KB blocks in the VIC-20 (BLK 1 - BLK 5) come from Bank 1 (The second 32KB in SRAM) of the SRAM.

This way all the addressable space in the VIC-20 is filled with RAM and therefore the maximum expansion with memory is achieved.

The additional information bits in Register 1 (zzzzz) control the write access to the RAM blocks. Bit 4 controls BLK 5, Bit 3 Controls BLK 3, Bit 2 Controls BLK 2, Bit 1 Controls BLK 1 and Bit 0 Controls BLK 0.

If the Bit is set to 0 then the RAM Block 0 can only be read not written.

The bits for Blocks 1 to 5 control the write operation. If the bit is not set (0) then it reads from Bank 1 of the RAM. If the Bit is set to (1) then it reads from Bank 2 of the RAM. In this way you have 64KB available (instead of 32KB). This way the RAM in Bank 2 cannot be overwritten. The Ram in Bank 2 functions with write protection (like ROM). Through this you can leave a program running without losing access to the RAM, one has a sort of RAM under a ROM, like in the C64.

Why do we need this? : one could for example program a machine code monitor to run in Bank 2 and display the contents of the whole of Bank 1.

This monitor would need almost no memory for itself.

SUPER RAM MODE (101zzzzz):

With Poke 39938,160 the SUPER RAM MODE of Final Expansion is activated.

Read operations come from the RAM from the selected Bank.

Write operations go to the RAM in the selected Bank.

Block 0 of the VIC-20 (3K Expansion) is switched on.

There are 32KB of SRAM enabled (4 x 8KB) at the addresses $2000 (Block 1), $4000 (Block 2), $6000 (Block 3) and $A000 (Block 5).

The usage of SUPER RAM is similar to a Flash read mode, except that RAM instead of EEPROM is used so that access to the full 512KB is possible.

The additional information in the Register (zzzzz) selects the 32KB Block of the SRAM.

In 512KB one has 16 x 32KB Blocks. The additional information can take the values 0 to 15.

What can you do with an 8 Bit computer like the VIC-20 with half a megabyte of RAM?

Who knows what innovative uses resourceful developers will find, one could for example easily save 3 full disks in there ...

RAM / ROM MODE (011zzzzz):

With Poke 39938,96 the RAM/ROM mode of the Final Expansion is enabled.

Read operations come from the RAM Bank 1 or optionally from the ROM Bank 0.

Write operations go always to the RAM, either in the Bank 1 (RAM Mode) or in the Bank 2 (ROM Mode).

The Block 0 of the VIC-20 (3K Expansion) is switched on.

The Bit 0 of Register 1 controls the write protection.

There is up to 35KB of SRAM available to configure (4 x 8KB + 3KB) at the addresses $0400 (BLK 0), $2000 (BLK 1), $4000 (BLK 2), $6000 (BLK 3) and $A000 (BLK 5).

The 3KB expansion (VIC-20 BLK 0) comes from Bank 0 (The first 32KB in SRAM) of the SRAM.

The four 8KB blocks in the VIC-20 (BLK 1 - BLK 5) come from Bank 1 (The second 32KB in SRAM) of the SRAM.

This way all the addressable space in the VIC-20 is filled with RAM and therefore the maximum expansion with memory is achieved.

The additional information in Register 1 (zzzzz) controls the selection of the VIC-20 Blocks. Bit 4 controls BLK 5, Bit 3 Controls BLK 3, Bit 2 Controls BLK 2, Bit 1 Controls BLK 1 and Bit 0 Controls BLK 0. If the Bit is set to 0 then the RAM Block 0 can only be read not written.

The Bits of the Blocks 1 to 5 control the access mode. If the Bit is not set (0) then access is to the RAM Bank 1. If the Bit is set (1) then read access is to the Bank 0 of the ROM (Flash) and write access is to the RAM Bank 1.

In this way there is access to a mix of RAM and ROM. In ROM mode the RAM in Bank 2 can be written to. This way one can simply copy ROM code into the RAM Bank.

Why do we need this?: The firmware can activate the ROM Block where the code has just been added. Simultaneously one can access the remaining RAM.

Flash Write Mode (001zzzzz):

With Poke 39938,32 the FLash Mode of the Final Expansion is activated.

Read access comes from the enabled Bank.

Write access goes to the ROM (Flash) in the selected Bank.

The Block 0 of the VIC-20 (3k Expansion) is enabled.

In this mode it is possible to examine and erase the Flash memory. In order to do this the special command sequence must be followed as prepared by the manufacturer of the Flash memory (See AM29F040 Data Sheet).

The Banking follows the same method as Super ROM mode.

The FE Firmware Flasher (fe3flash) uses this method.