vFORTH 1.7

ZX Spectrum Next version

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Introduction
&
Technical Information

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1 Foreword

This document introduces a Forth implementation suitable to run on *Sinclair ZX Spectrum Next* as a “**dot command**”.

This is more a technical reference and not an introductory book to Forth: To learn Forth language or for a good reference I suggest the book "Starting FORTH" - Leo Brodie (1981, Forth Inc.). The PDF is hopefully available at Forth Inc web-site. The first edition is old enough to stick on 16-bits integer numbers. In this perspective, almost all Forth source described in Leo's book are available in Screens from #800 upward.

This is a working and functional piece of software, but there are many things still to do to cope with all the new *Sinclair ZX Spectrum Next*'s functionalities – Repository at https://github.com/mattsteeldue/vforth-next.

In essence, this is a *quasi* standard Forth based on my previous work vForth **version 1.413** available somewhere in the Internet at https://sites.google.com/view/vforth/vforth1413 and at https://github.com/mattsteeldue/vforth. Among the differences is that vForth now uses a single dedicated file on SD to provide **`BLOCK`** / Screen storage facility, while previous versions used ZX Microdrive cartridges or DISCiPLE disks. See command **`USE`** to choose a different **`BLOCK`** file.

The latest **version 1.7** splits the dictionary structure in two parts, a *name-space* and a *code-space*, by exploiting a few 8K RAM pages fitted at MMU7. This provides a more efficient memory usage so that now there is much more memory available for actual code. This also means there is nomore fear in create *long-name definitions*, since the definition's name uses *heap memory* and not *main memory*. For *heap-memory* capability see § 6.3.

From previous **versions 1.6**, vForth runtime is faster than any previous version, thanks to the idea of dedicating more Z80 registers to keep the internal status of Forth's virtual machine and the Inner-Interpreter, see § 3.7.1.

Starting from **version 1.52**, the behavior of `VARIABLE` is *standard* and doesn't need an initial value: this means that some older syntax *à la* White Lightning may not work properly, since it leave some spurious data on the stack that isn't used by `VARIABLE` anymore.

Starting from version **vForth 1.51**, this Forth comes with two flavors: *Direct-Threaded* or *Indirect-Threaded* code. Direct-Threaded offers some more speed at the cost of more memory allocation for each colon-definition. See § 3.7.1 for technical detail.

1.1 MIT License

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This very same MIT License can be viewed from within vForth environment via **`VIEW LICENSE.MD`** provided that **`VIEW`** is made available via **`NEEDS VIEW`**.

1.2 Typos and suggestions

I, the author am not a native English speaker and you, very likely, will find grammatical errors. In this case, it would be kindly appreciated if you could drop me a line with any suggestion and/or correction at *matteo* -underscore-*vitturi@yahoo.com.*

1.3 Acknowledgment

Many thanks to Rob Probin for his invaluable suggestions and insights.
Special thanks goes to Roland Herrera who helped to edit one of the first issues of this documentation.
Special mention to Albert van der Horst for his 8080 inspirational Assembler library.

1.4 Document structure

Chapter 2 describes how to install, activate and get acquainted with the Forth environment, briefly exposing various basic options and utilities, such as chosing case-sensitive, editing screens & blocks and feeding your source code to build new definitions. It also describes how to create a standalone executable via **ZAP**.
Chapter 3 lists some useful libraries and utilities you can use while in Forth that can be imported in your session using **NEEDS**. Here are some details:
Chapter 3.1: Since the old fashion Screen/Block facility is a very quick way of coding in Forth, **EDIT** a **Full Screen Editor** is available, and to handle *larger text files* I've coded the **Large file EDitor** aka LED (**Chapter 3.3**) that is able to handle files as large as ca. 17.000 rows, 85 characters per row; it's a “work-in-progress” though.
Chapter 3.2 introduces **GRAPHICS** library to manage various **Modes** and **Layers** along with **Color** and **Attributes** definitions.
Chapter 3.4 introduces the **MOUSE** facility relying upon the **Interrupt Service Routine** library (**Chapter 3.5**): see the demo demo/color-picker.f for a nice example of interrupt-driven mouse cursor movement.
Chapter 3.6 provides an old fashion **BLOCK** oriented **Search** and **Locate** Utility.
Chapter 3.7 explains the inner parts of Forth introducing the **SEE** Debugger Utility.
Chapter 3.8 shows how to exploit the Standard-ROM **FLOATING point** calculator.
Chapter 3.9 shows the obsolete **Line Oriented Editor** that's the foundation for the aforementioned **Full Screen Editor**.
Chapter 3.10 introduces the **ASSEMBLER** vocabulary, an alternative way to code Z80. There are a few examples.
Chapter 4 gives some deeper insight and technical information about the Inner-interpreter.
Chapter 5 is a straight list of error messages.
Chapter 6 provides detailed information of **Forth Dictionary** where each definition is explained in a formal way.
Chapter 6.1 is the “core” dictionary list, where almost all definitions are available at COLD start, then
Chapter 6.2 introduces the optional set of definitions that provides the **Case-Of structure**.
Chapter 6.3 describes the **Heap Memory Facility** to access the large quantity of memory available: from this **Version 1.7** Forth's dictionary itself relies upon this Heap Memory Facility allowing the the most main memory to be actual code.
Chapter 6.4 introduces the **Testing Suite**, to show that vForth *wants to comply* to modern Standard.
Chapter 6.5 for other utilities.
Chapter 7 briefly shows the memory map.

1.5 Legend

Much effort was put to adhere to the following convenctions:

`Courier New`	is used whenever a Forth definition is referenced or to indicate some typed-in source code.
Calibri Bold	to highlight something important, like filenames, messages, or key-strokes.
Calibri	is used elsewhere

All definitions explained in the dictionary pages are introduced in the form:

`A-WORD        n1 n2 ... ---  n3 n4 ...`

where "`n1 n2 ...`" represents the Stack status before `A-WORD` is executed, and "`n3 n4 ...`" represents the Stack status after `A-WORD` is executed. Special behavior, such as `IMMEDIATE` definitions are explained properly.

`a`	memory address	16 bits
`b`	byte, small unsigned integer	8 bits
`c`	character	8 bits, but often only lower 7 are significant.
`d`	signed double integer	32 bits
`fh`	file-handle (NextZXOS)	8 bits
`fp`	floating point number (see **§3.8**)	32 bits
`ha`	heap-pointer address (see **§6.3** and `>FAR`)	16 bits.
`n`	signed integer	16 bits
`u`	unsigned integer	16 bits
`ud`	unsigned double integer	32 bits
`f`	flag: a number evaluated as a boolean	16 bits
`ff`	false flag: zero	16 bits
`tf`	true flag: non-zero	16 bits
`nfa`	name field address	16 bits
`lfa`	link field address	16 bits
`cfa`	code field address	16 bits
`pfa`	parameters field address	16 bits
`xt`	execution token	16 bits
`cccc`	character string or definition-name available in the vocabulary	
`...`	a list of definitions	
TOS	top of calculator stack	

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2 Getting started

2.1 Installation

The most recent version of this software can be downloaded from GitHub repository as .zip file at

https://github.com/mattsteeldue/vforth-next/tree/master/download

The same executable programs are available in the same repository:

https://github.com/mattsteeldue/vforth-next/tree/master/SD/tools/vforth

Unzip or copy the software to "C:/tools/vForth" directory inside your Next's SD card so it appears in the following directory hierarchy:

doc/	where I keep some help text files and this very same document.
inc/	contains source files of single definitions available via **`NEEDS cccc`**.
lib/	same as inc/ but these source files are a collection of several definitions that forms a “library utility”.
src/	among others, the source file of this Forth System.
test/	contains an adaptation of John Hayes’ Test Suite that tries to make this Forth more *standard*.
util/	with some Perl script to manage with !Blocks-64.bin file I collect over the time.
demo/	some useful demos.

↑Name	Ext	Size	Date	Attr
[..]		<DIR>	08/08/2023 19:07	----
[demo]		<DIR>	16/04/2023 16:44	----
[doc]		<DIR>	01/07/2023 19:00	----
[inc]		<DIR>	04/06/2023 23:01	----
[lib]		<DIR>	01/06/2023 22:50	----
[src]		<DIR>	16/04/2023 16:47	----
[test]		<DIR>	05/02/2023 00:24	----
[util]		<DIR>	16/09/2021 21:43	----
!Blocks-64	bin	16.777.216	08/08/2023 19:04	-a--
Forth17	bas	555	08/08/2023 18:52	-a--
Forth17_loader	bas	1.153	08/08/2023 18:51	-a--
forth17d	bin	9.999	08/08/2023 18:42	-a--
LICENSE	md	1.076	08/08/2023 19:06	-a--
ram7	bin	8.192	08/08/2023 18:42	-a--

Forth17_loader.bas loads **Forth17d.bin** code that is the latest version.

2.1.1 dot-command

In addition to /tools/vForth directory, the .zip file has a /dot directory which contains `vforth` binary dot-command that has to be manually copied to directory C:/dot. Such a dot-command requires a normal installation as shown in paragraph 2.1.

If you wish to use a different directory instead of C:/tools/vforth, you need to modify the paths in the above Basic programs *and* the manually patch the path+filename specified inside the `vforth` binary file...

2.2 Activation / Deactivation and brief tutorial

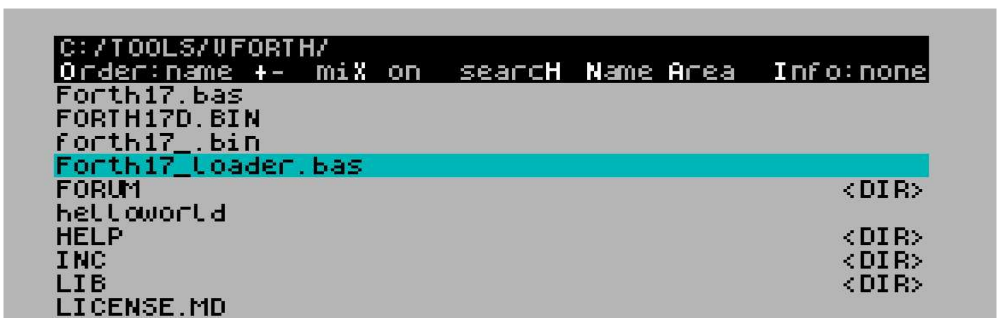
The Forth System can be activated in two ways:

- running dot-command `.vforth` from command line or NextBasic.
- running a Basic program **C:/tools/vforth/forth17_loader.bas**.

Both should be equivalent, even thouth using the dot-command loads at address $2000 and has some OS dependencies.

To terminate the Forth session exiting to Basic you can type **`BYE`**.

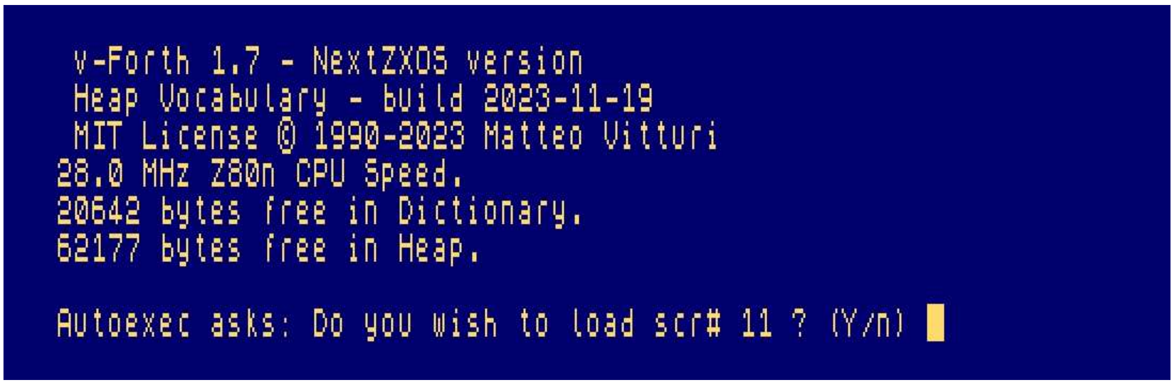
The second way can be performed using the Browser and selecting it, then hitting ENTER.



The Basic loader **forth17_loader.bas** frees upper memory setting RAMTOP to a very low address 25345 and usually loads **ram7.bin** to BANK 16, then **forth17d.bin** to few bytes above RAMTOP and then it loads a smaller Basic launcher **forth17.bas** that you can customize for your purposes.

In both ways, a Splash screen displays the Version Number and the Build Date followed by some technical system information that are produced by the Auto-Start sequence of **Screen # 11**. In fact, within a few seconds the system will ask if you would like to "**`Run Scr # 11 autoexec`**": the only way to refuse is by using the **[N] key**. However, it's a good idea to allow Forth to continue to LOAD **Screen # 11** which in turn loads a few useful utilities making available, among the other definitions, two particular definitions: **`EDIT`** the "**Screen Editor**" and **`SEE`** the "**Debugger Inspector**". This phase is executed only at *first* startup, but you can run it again using **`AUTOEXEC`**.

In general, in any source-file available in these directories to be imported, I always put some "print" statement just to show the user what is going on or what is being loaded, this is because often, whenever nothing moving nor blinking on the screen, a person is induced to think the machine just crashed.



The Basic launcher **forth17.bas** usually auto-starts the first time at line `20`, so you usually won't notice, but just in case you `STOP` it or the Forth system encounters a ROM Error that forces it to suddenly return to Basic, you have two main choices:

a. type RUN at Basic prompt : This does a **`WARM`** Forth-start, preserving your previous work and buffers status.

b. type RUN 20 at Basic prompt: This does a **`COLD`** start, that should reset all as if you had just loaded from SD card.

In either case, file-handles aren't released.

2.3 Case-insensitive and Case-sensitive option

By default, the Forth interpreter is *case-insensitive*, so you can type your commands using lower-case or upper-case or a mix of them with no difference. To enable or disable the case-sensitive interpretation you can use **`CASEON`** and **`CASEOFF`** definitions.

The case-insensitive option applies to the Intepreter's dictionary search only or when using a definition that uses **`(COMPARE)`** primitive such as **`GREP`**. A new definition-name retains the exact case it was coded with.

2.4 Block / Screen system

This Forth System comes with a file named `!Blocks-64.bin` that provides the simplest mass-storage system usually available in old-days Forth systems.

To choose a different file there are two ways:

- at startup from Basic, you can specify a filename as parameter after the “dot-command” itself; if such a file exists, this makes it the default for the current session. For example:

  `.vforth /tools/filename.bin`

- Inside vForth, at “ok prompt”, invoking the **`USE`** definition (§ 6.1), for example:

  `USE /tools/filename.bin`

A **`BLOCK`** is identified by its *number*, an integer between 1 and 32,767, and can be temporarily kept in RAM in a **`BUFFER`** identified by the same *number* in a memory area that can be addressed, inspected and modified. The dedicated memory area that lies between **`FIRST`** and **`LIMIT`**. In this system there are seven buffers.

Using **`UPDATE`**, the most recent referred **`BUFFER`** is marked for re-write to file at the moment the system will request the same buffer to keep a different block or when **`FLUSH`** is used.

On this Forth system, two **blocks** forms a **Screen** that can be edited using the “Full Screen Editor” (see §**3.1**) utility available after you type:

`NEEDS EDIT`

Each **`BLOCK`** has 512 bytes and each **Screen** is 1 KByte so it can store text in 16 lines and 64 columns . A **`BLOCK`** can be used as a *virtual-memory* area where you can persistently store anything you like. For instance, you can think a **`BLOCK`** as an 256-elements *integer array* with persistance.

2.4.1 Block File Format

The file provided as default (`!Blocks-64.bin`) is 16 MBytes long and it is a simple ordered concatenation of all blocks available, so that block # 1 starts at file-offset 0 and ends at file-offset 511, block # 2 starts at offset 512 and ends at offset 1023, and so on. There is no block # 0 and the greatest number available is then 32,767 (16,383 **Screens**).

You can use your own file, but that the first Screens must be reserved for error messages and such things.

In particular, Screens # between 4 and 7 must contain the standard **`MESSAGE`**, those listed in § 5. If you omit to have them there, the system will become quite foolish, since any **`ERROR`** message would be something totally blank or random.

A **Block-number** is always twice the corresponding **Screen-number**, for example **Screen # 11** uses block # **22** and **23**. You may argue that this way **`BLOCK`** *number* 1 is never accessible, and in fact it is reserved for internal purposes (see **`NEEDS`**).

Accessing the first blocks is faster than the others, so that reading the last available block using, for example

`DECIMAL 16383 LIST`

will take a noticeable amount of time. This may depend on how **`F_SEEK`** primitive is implemented.

2.5 Character size

In this Forth implementation I prefer LAYER 1,2 display mode to allow 64 character per line: this is quite necessary in order to be able to display a whole 1024 characters Screen in a single go.

If you prefer LAYER 1,1 you can add a line 61 in **forth17.bas** wrapper as follow

61 LAYER 1,1: PRINT CHR$ 30; CHR$ 4;

to switch to LAYER 1,1 and condensed character set. The result is quite poor in my opinion.

You can also change **LAYER** mode using some Layer-related definitions available after **NEEDS GRAPHICS** or **NEEDS LAYERS**.

2.6 Source feeding and output spooling

Before entering Forth, the Basic launcher is allowed to open text-files via OPEN#, for instance

```
OPEN# 13,"o>output.txt"
```

that can be later selected for output in Forth via **13 SELECT** to collect any output you send to this output-channel. To restore sending output to video there is an easy **VIDEO** definition that simply does **2 SELECT**.

Two specific definitions allow you to include (and compile) source from any file i.e. **INCLUDE** and **NEEDS.**
For example,

```
INCLUDE demo/chomp-chomp.f
```

or

```
NEEDS GRAPHICS
```

Moreover, you may edit almost any souce text-file using **LED**, the built-in editor available via

```
NEEDS LED
```

See § 3.3 “LED – The Large EDitor” for more details.

2.7 Creation of standalone executable

If we want to create an executable file of a vForth game or program you have to use the **ZAP** definition (§6.1).

The purpose is to create a Basic program that loads three binary memory images that contains the current state of the whole vForth system that can be resumed later. See the dictionary explanation of **ZAP** definition at §6.1.

2.8 Number literals interpretation

Numbers interpretation, at prompt or during compilation, depends on current **BASE**. The two definitions **DECIMAL** and **HEX** change the current **BASE** to decimal and hexadecimal respectively. The interpreter **NUMBER** accepts an optional number-prefix “$” or “%” to temporarily modify **BASE** accordingly for the current number only: “$” for hexadecimal (base 16), “%” for binary (base 2). The side effect is that `$` and `%` alone are somhow equivalent to `0`.

The “unary-sign” must be the first character interpreted, even before any base-prefix “$” or “%”.

Double-Integer numbers interpretation accept any of the following five punctuation marks: **, . / - :**

For example:

```
120,000    23:59:59    1/23/45    3.14159
```

are all legal double-length numbers.

2.9 Definitions grouped by category

Here is my own personal classification of most definitions available in this system.

2.9.1 Comments

Block oriented	**Line oriented**	**No-operation**
(…)	\ …	`NOOP`

2.9.2 Stack manipulation

Broadly speaking, a *Calculator-Stack* entry is a 16-bits number (§ 4.2) i.e. a **`CELL`**, while a Double-Integer value is a 32-bits number (§ 4.3) which needs two `CELLS` in the Calculator-Stack, the higher significant part on top of stack.
Return-Stack is used on entering-exiting phase of a definition *and also* to keep track of **`DO`** – **`LOOP`** index and limit.
Floating-Point-Stack is the standard ZX Spectrum floating-point Calculator Stack that is accessible after loading the Floating-Point-Option (§ 3.8). See "Technical specifications" (§ 4) for more details.

Single Cell	**Double cells**	**Return Stack**	**Stack Inspection**	**Floating point Stack**
DUP OVER DROP SWAP NIP TUCK ROT -ROT PICK ROLL ?DUP -DUP	2DUP 2OVER 2DROP 2SWAP 2ROT	>R R> R@ I' DUP>R R>DROP	DEPTH .S	>F F> FOP

2.9.3 Comparison

Comparison involves the top element or the two top elements available on the Calculator Stack. Double precision integers (§ 4.3), formed by two elements each, involves twice the elements, obviously.

Against zero	**Signed**	**Unsigned**	**Double-precision**
0= 0< 0> NOT	= < > <> MIN MAX	U<	D0= D< D= DU<

2.9.4 Output

Any output is sent to video by default, but the actual device depends on which Stream is chosen via **`SELECT`**.

Single-integer definition **Stack Value**	**Double-integer definition** **stack value and** **Floating point Stack**	**String**	**Other**

`.`
`.R`
`?`
`U.`
	`D.`
	`D.R`
	`F.`
		`."`
		`.(`
		`.C`
		`SPACE`
		`SPACES`
		`EMIT`
		`EMITC`
		`INVV`
		`TRUV`
		`MARK`
		`MESSAGE`
		`TYPE`
			`SPLASH`
			`CLS`
			`CR`
			`DEVICE`
			`SELECT`

2.9.5 Integer Arithmetics

Normally all definitions act upon 16-bits (signed or unsigned) integers (§ 4.2).
Definitions that act upon 32-bits integers (§ 4.3) have names that begin with **D** for *double*.
Mixed definitions, that involve both 16-bits and 32-bits integers begin with **M** for *mixed*.

Arithmetics	**Signed / Unsigned**	**Double**	**Constants**

`+`
`-`
`*`
`/`
`/MOD`
`MOD`
`2/`
`2*`
	`+-`
	`ABS`
	`NEGATE`
	
	`UM/MOD`
	`UM*`
		`D+`
		`D-`
		`DNEGATE`
		`DABS`
		`D+-`
			`0`
			`1`
			`2`
			`3`
			`-1`
			
			`PI`

Mixed	**Bitwise**	**Increment/Decrement**	**Floored / Simmetric Division**

`M+`
`M*`
`M/`
`M/MOD`
`*/`
`*/MOD`
	`AND`
	`OR`
	`XOR`
	`NOT`
	`RSHIFT`
	`LSHIFT`
	`FLIP`
	`INVERT`
	`SPLIT`
	`UPPER`
		`1+`
		`2+`
		`CELL+`
		`1-`
		`2-`
		`CELL-`
			`FM/MOD`
			`SM/MOD`

2.9.6 Memory

Normally all definitions act upon 16-bits (signed or unsigned) integers (§ 4.2).
Definitions that act upon 32-bits integers (§ 4.3) have names that begin with **2** for *two-cells*.

Store & Fetch	**Memory chunks**	**Pointers & Variables**	**8K RAM Paging**

`!`
`@`
`2!`
`2@`
`C!`
`C@`
`+!`
`TOGGLE`
`TO (used with VALUE)`
`+TO`
	`FILL`
	`ERASE`
	`BLANK`
	`CMOVE`
	`CMOVE>`
	`PAD`
	`BUFFER`
	`BLOCK`
	`CELL`
	`CELLS`
	`ALIGNED`
	`DUMP`
		`RP@`
		`RP!`
		`SP@`
		`SP!`
		`S0`
		`R0`
		`USE`
		`PREV`
			`S"`
			`HEAP`
			`FAR`
			`POINTER`
			`H"`
			`+"`
			`+C`
			`>FAR`
			`<FAR`
			`HEAP-INIT`
			`HEAP-DONE`
			`SKIP-PAGE`

2.9.7 Flow control

Counted Loop	**Unconted Loop**	**Conditionals**	**System related**

`DO`
`?DO`
`LOOP`
`+LOOP`
`LEAVE`
`I`
`I'`
`J`
`K`
	`BEGIN`
	`WHILE`
	`REPEAT`
	`UNTIL or END`
	`AGAIN`
	
	`BACK`
		`IF`
		`THEN`
		`ENDIF`
		`ELSE`
		`CASE`
		`ENDCASE`
		`OF`
		`ENDOF`
		`EXEC:`
			`BYE`
			`AUTOEXEC`
			`COLD`
			`WARM`
			`ABORT`
			`ERROR`
			`CALL#`
			`INTERPRET`
			`EXECUTE`
			`QUIT`
			`BASIC`

2.9.8 I/O and Hardware

I/O Ports	**HW Registers**	**Keyboard**	

`P!`
`P@`
	`REG!`
	`REG@`
	`MMU7!`
	`MMU7@`
		`?TERMINAL`
		`KEY`
		`CURS`	

2.9.9 Definition related

Creators	**Status & Variables**	**Compilation / Interpretation**	**Dictionary Allocation**
:	?COMP	COMPILE	ALLOT
;	?CSP	[COMPILE]	,
:NONAME	?ERROR	[CHAR]	C,
CREATE	?EXEC		."
VARIABLE	?LOADING	[	.(
CONSTANT	?PAIRS	]	COMPILE,
CODE	?STACK		LITERAL
EXIT	STATE		DLITERAL
!CSP	CSP		
DOES>			
<BUILDS			
VALUE			
USER			

2.9.10 BLOCK / Screen related

Block & Buffer	**Input**	**Block-file primitives**	**Variables & Constants**
.LINE	LOAD	BLK-INIT	TIB
BLOCK	-->	BLK-READ	FIRST
EMPTY-BUFFERS	QUERY	BLK-SEEK	LIMIT
FLUSH	ACCEPT	BLK-WRITE	SOURCE-ID
INDEX	ENCLOSE		BLK
LIST	CHAR		>IN
UPDATE	EXPECT		OUT
OPEN<	WHERE		SCR
	LOCATE		OFFSET
	GREP		BLK-FH
	BSEARCH		BLK-FNAME
			#SEC
			#BUFF
			SPAN
			B/BUF
			B/SCR
			C/L

2.9.11 Numbers & strings

Number to string	**Base**	**Interpretation**	**Variables**
<#	BASE	NUMBER	NMODE
#	HEX	(NUMBER)	HLD
#S	DECIMAL	(SGN)	DPL
#>	BINARY		FLD
SIGN	OCTAL		PLACE
HOLD			EXP

2.9.12 Dictionary related

Input Stream	Vocabulary manipulation	Definition data	Variables & Constants
' -FIND INCLUDE MARKER NEEDS CASEOFF CASEON	FORTH DEFINITIONS ASSEMBLER SMUDGE RENAME FORGET ALIGN ID.	CFA PFA NFA LFA <NAME >BODY TRAVERSE .WORD	WIDTH WARNING FENCE DP VOC-LINK CONTEXT CURRENT BL

2.9.13 Editor

Screen oriented	Line oriented		File oriented
EDIT B N L SAVE	H D RE INS S E	.PAD P -MOVE TEXT LINE	LED LED-EDIT LED-SAVE LED-FILE

2.9.14 NextZXOS

File hook	Directory hook	+3DOS hook	Other
F_SEEK F_CLOSE F_SYNC F_FGETPOS F_READ F_WRITE F_OPEN TOUCH UNLINK	F_OPENDIR F_READDIR DIR PWD CD	M_P3DOS	R# LP HANDLER ZAP

2.10 Known bugs, workarounds, and improvement needed

INTERPRET In some cases, interpretation of long structure via **LOAD** cannot cope with **BLOCK**s boundaries within the same Screen. This means, for example, that you cannot start an **ENUMERATED** structure in the first **BLOCK** of a Screen and continue it in the next one.

INCLUDE The **INCLUDE**d source text file *must end with an empty line*, otherwise the system crashes usually showing some vertical grid. **NEEDS** suffers the same bug since it uses **INCLUDE**.

NEEDS In case of interpretation/compilation error, the file/handle remains open and you have to manually close it using something like **2 F_CLOSE DROP** and you cannot use **REMOUNT** until then.

OPEN< At the moment, this definition is experimental and can be used only in interpretation mode.

BCOPY When used repeatedly, it seem to miss half Screen every three, expecially when you work backard in block number . Maybe this depends from the number of **BUFFER**s available. A simple workaround is to **FLUSH** often.

LED Pressing [BREAK] will stop any I/O operations: if not correctly used, may produce data-loss.

3 Utilities

WARNING: some of these definitions are still under development and specifications may change in the future. Much effort is put to keep backward compatibility.

3.1 The Full Screen Editor Utility – Screen oriented

The **`EDIT`** definition is available after you type: **`NEEDS EDIT`** (or in the old way **`190 LOAD`** if the source it is still there and you didn't reused these Screens).

On this Forth system, as in many others, a Screen has 1,024 bytes of data spread in 16 lines, 64 bytes each.

This "Full Screen Editor Utility" is invoked using the **`EDIT`** definition that enters a simple page-editor that allows modifying the current Screen, i.e. the one contained in **`SCR`** variable. During **`EDIT`**, you are allowed move to the next Screen or to the previous one using the commands explained below.

Remember: to *quit* the **`EDIT`** phase, you have to use [**Edit**] key followed by **[Q]** key, in a way that mimics Unix **vi** editor.

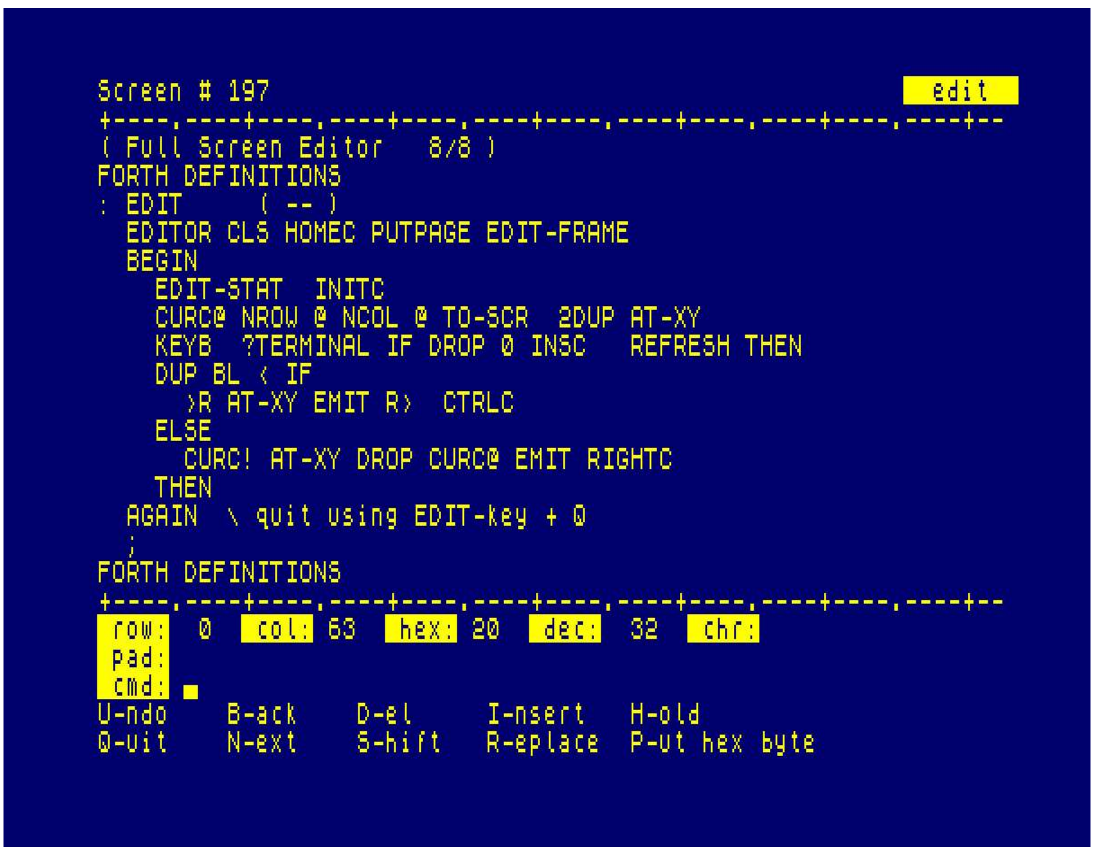
This editor works only if the display-mode allows 64 character per line at least.

EDIT ---

For example, to select, show and edit **Screen # 197** you can type:

`DECIMAL 197 LIST` (to set 197 the "current screen")

`EDIT` (to enter the editor on "current screen")



The previous picture shows a header reporting the Screen number and a line-ruler followed by 16 lines that make up the Screen itself.

A flashing cursor is visible at home position: The cursor has two flashing mode to distinguish **CAPS LOCK** enabled – the higher flashing cursor – (█) or disabled – the half flashing cursor – (▄) .

The cursor keys, **[Shift]** key + **5 / 6 / 7 / 8** keys, allow the flashing cursor to be moved across the screen to point the current position inside the Screen, so text can be typed at any position on the Screen.

Current cursor positions (**row** number and **col**umn number) are shown on the bottom status bar along with current character, **dec**imal ASCII code and **hex**adecimal code of it.

Pad line shows the current **PAD** content. Line oriented commands handle and work with **PAD**. See the "Line Editor" chapter (§3.9). When **PAD** contains garbage, the whole screen may become corrupted: in this case you can type **[Edit]** + **H** to copy the current line to **PAD** that should fix that issue.

After the **[Edit]** key (Shift + 1 using standard PC keyboard**)** the Editor recognizes the following single or double key-stroke commands:

> **[Edit] + Q** : **Q**uit `EDIT` Utility
> **[Edit] + U** : **U**ndo, that is re-read current screen from disk ignoring any modification done since last **FLUSH**. This feature is quite important, since it does for a single Screen what **EMPTY-BUFFERS** does for all of them.
> **[Edit] + H** : take (or **H**old) current line content and keep it in **PAD**
> **[Edit] + R** : **R**eplace current line with the current **PAD** content.
> **[Edit] + S** : make **S**pace at current cursor position shifting lower lines down; last line will be lost.
> **[Edit] + D** : **D**elete current line shifting up lower line, but a copy is copied to **PAD** before deletion, like **H**
> **[Edit] + I** : **I**nsert at current cursor line position the content of **PAD**: it does commands **S** and **R**.
> **[Edit] + N** : go to **N**ext screen
> **[Edit] + B** : go **B**ack to previous screen
> **[Edit] + P** : accepts *two hexadecimal digits* representing a byte and **P**ut it at cursor position. This way, non-printable characters, i.e. ASCII code between 0 and 31 ($00 - $1F), can be stored inside a Screen, but care must be paid to avoid corrupting the display because most of them are *control characters* and some of them are used. Characters with ASCII code between $80 and $FF can be stored in a Screen, but they are emitted to video translated to the corresponding codes between $00 and $7F.

any other key has no meaning and returns the flashing cursor back to its position.

[Delete] (that is **Caps-Shift + ZERO**) removes a character at current cursor position, shifting left the rest of the line.

[Break] (that is **Caps-Shift + SPACE**) inserts a space at current cursor position, shifting right the rest of the line.

[Caps-Lock] (that is **Caps-Shift + 2)** accounts for a keystroke, but it is interpreted by the system to change the Caps-Lock state switching between enabled (█) and disabled (▄).

Beware, any modification you do immediately affects the underlying Buffers, so if you mess things too much so that **[Edit] + U** is not enough, there is only a way to recover it, to quit and type **EMPTY-BUFFERS** to erase all buffers without flushing them to disk, before it's too late.

This "Full Screen Editor" is a work-in-progress and can be improved if needed either acting on Screens between 190 and 197 or editing **./lib/edit.f** source file.

3.2 Graphics mode and Layer facility

The following definitions are available after you type **NEEDS GRAPHICS**.
To forget this library from dictionary you can type **NO-GRAPHICS** or **FORGET GRAPHICS**.
This library is still work-in-progress because I'm improving it every so often.

The ZX Spectrum Next's machine can handle several Graphic-Modes and vForth is able to use almos all of them.

In all the following definitions, the x-coordinate is the vertical distance from the top-left corner of the grid, the y-coordinate is the horizontal distance from the top-left corner of the grid

LAYER! n ---

This definition changes Graphic-Mode. The parameter n can be one of the following values:

- **00** to switch to **Layer 0** - Standard Spectrum (ULA) mode, 256 w x 192 h pixels, 8 colors total (2 intensities), 32 x 24 cells, 2 colors per cell. Equivalent to Basic's LAYER 0.
- **10** to switch to **Layer 1,0** - LoRes (Enhanced ULA) mode, 128 w x 96 h pixels, 256 colors total, 1 color per pixel. Equivalent to Basic's LAYER 1,0.
- **11** to switch to **Layer 1,1** – Standard Res (Enhanced ULA) mode, 256 w x 192 h pixels, 256 colors total, 32 x 24 cells, 2 colors per cell. Equivalent to Basic's LAYER 1,1.
- **12** to switch to **Layer 1,2** – Timex HiRes (Enhanced ULA) mode, 512 w x 192 h pixels, 256 colors total, only 2 colors on whole screen. Equivalent to Basic's LAYER 1,2.
- **13** to switch to **Layer 1,3** – Timex HiColour (Enhanced ULA) mode, 256 w x 192 h pixels, 256 colors total, 32 x 192 cells, 2 colors per cell. Equivalent to Basic's LAYER 1,3.
- **20** to switch to **Layer 2** – 256 w x 192 h pixels, 256 colors total, one color per pixel. Equivalent to Basic's LAYER 2,1.

To ease of use, this definition accepts n which can be expressed both in **DECIMAL** or in **HEX**, without confusion, and since there is no ambiguity, the following two lines gives the same result

```
HEX     12 LAYER!
DECIMAL 12 LAYER!
```

This primitive definition *just* changes Graphics-Mode without any other side effect. Instead, the hereby definitions **LAYER0**, **LAYER10**, **LAYER11**, **LAYER12**, **LAYER13** and **LAYER20** also modify the overall behavior of some other graphics definitions.

The following table shows the peculiarity of each of six Graphics-Mode when applicable

	L0	L11	L12	L13	L10	L2
Char-Size	8	4	8	4	4	4
V-RANGE	0C0	0C0	0C0	0C0	060	0C0
H-RANGE	100	100	200	100	080	100
PIXELADD	L0	L0	L12	L0	L10	L2
POINT	L0	L0	L0	L0	L1	L1
PLOT	L0	L0	L0	L0	L1	L2
XPLOT	L0	L0	L0	L0	L1	L2
PIXELATT	L0	L0	na	L13	na	L2
XY-RATIO	1	1	2/	1	1	1
EDGE	=	=	=	=	L1	L1

LAYER0 ---

Set screen mode to Standard ULA, legacy ZX Spectrum mode, also set the characters to 4 pixel wide, and modify the overall behavior of all graphics definitions to work with this specific pixel resolution.

LAYER10 ---

Set screen mode to LoRes mode, set the characters to 4 pixel wide, and modify the overall behavior of all graphics definitions to work with this specific pixel resolution.

LAYER11 ---

Set screen mode to Standard Res (Enhanced ULA) mode, set the characters to 4 pixel wide, and modify the overall behavior of all graphics definitions to work with this specific pixel resolution.

LAYER12 ---

Set screen mode to Timex HiRes (Enhanced ULA) mode, set the characters to 8 pixel wide, and modify the overall behavior of all graphics definitions to work with this specific pixel resolution, for example, the correct aspect-ratio for **CIRCLE** is enforced.

LAYER13 ---

Set screen mode to Timex HiColour (Enhanced ULA) mode, set the characters to 4 pixel wide, and modify the overall behavior of all graphics definitions to work with this specific pixel resolution.

LAYER2 ---

Set screen mode to Layer 2, set the characters to 4 pixel wide, and modify the overall behavior of all graphics definitions to work with this specific pixel resolution.

IDE_MODE! **n** ---

This is a primitive definition to switch Graphic-Mode via NextZXOS using **M_P3DOS** call $01D5
It's called by **LAYER!** that prepares n in a suitable way. This definition is also available via NEEDS **IDE_MODE!**

LAYER0	:	$0000
LAYER10	:	$0100
LAYER11	:	$0101
LAYER12	:	$0102
LAYER13	:	$0103
LAYER2	:	$0200

IDE_MODE@ --- hl de bc a

This is a primitive definition to query current Graphic-Mode via NextZXOS using `M_P3DOS` call $01D5.
Usual result are:

LAYER	:	hl	de	bc	a	(a in binary)
LAYER0	:	$1620	$000F	$0800	$00	(00 00 00 00)
LAYER10	:	$0C20	$FF00	$0400	$01	(00 00 00 01)
LAYER11	:	$1840	$000F	$0400	$05	(00 00 01 01)
LAYER12	:	$1840	$0000	$0800	$09	(00 00 10 01)
LAYER13	:	$1840	$0038	$0400	$0D	(00 00 11 01)
LAYER2	:	$1840	$0038	$0400	$02	(00 00 00 10)

3.2.1 Low-level definitions

The following definitions **PIXELADD**, **PIXELATT**, **PLOT** and **POINT** are coded in assembler for maximum performance.

ATTRIB --- n

Value that specifies the byte used as color-attribute in all subsequent graphics command. To modify it you have to use the **VALUE - TO** semantics

```
DECIMAL  216  TO  ATTRIB
```

The value of **ATTRIB** is saved across any Layer switch so that each Graphic-Mode keeps its own value.

PIXELADD x y --- n

Depenging on current Graphic-Mode, determine address of a pixel and fit MMU7 8K page if needed.

PIXELATT x y --- n

Depenging on current Graphic-Mode, determine address of a pixel and fit MMU7 8K page if needed.

PLOT x y ---

Depenging on current Graphic-Mode, plot a pixel using current **ATTRIB**.

POINT x y --- c

Depenging on current Graphic-Mode, it returns the attribute value of a pixel.
For Layer 1,0 and Layer 2 modes this is simply the sequence **PIXELADD C@**.
For Layer 0 Layer 1,1 Layer 1,2 and Layer 1,3 modes, this definition returns a true-flag if the pixel is set or a false-flag if the pixel is unset.

3.2.2 High-level definitions

CIRCLE **x y r** **---**

Draw a circle with center at `x y` and radius `r` using the current **ATTRIB** color and Graphic-Mode. As stated above, x-coordinate is the vertical and y-coordinate is horizontal. This definition does not use

DRAW-LINE **x0 y0 x1 y1** **---**

Draw a line from `x1 y1` to `x0 y0` using the current **ATTRIB** color and Graphic-Mode. As stated above, x-coordinate is the vertical and y-coordinate is horizontal.

PLOT **x y** **---**

Draw a pixel at `x y` using the current **ATTRIB** color and Graphic-Mode. As stated above, x-coordinate is the vertical and y-coordinate is horizontal.

PAINT **x y** **---**

Experimental: Try to paint a well-shaped convex area, provided that `x y` is some “center” to start. As stated above, x-coordinate is the vertical and y-coordinate is horizontal.

3.2.3 Colors & Attributes

Here is a set of definition that invoke the Standard-ROM routines to change the screen colors. All these definitions end with a dot (.) to spacify that it works via `EMIT` and to avoid confusion with other definitions.

.BORDER **b** **---**

Immediately set the current BORDER color. It uses ROM routine $2297 via **CALL#**.

.BRIGHT **b** **---**

Depending on on current Graphics Mode, set the current BRIGHT attribute for any subsequent output operations.

.FLASH **b** **---**

Depending on on current Graphics Mode, set the current BRIGHT attribute for any subsequent output operations.

.INK **b** **---**

Depending on on current Graphics Mode, set the current INK color for any subsequent output operations.

.INVERSE **b** **---**

Depending on on current Graphics Mode, set the current INVERSE attribute for any subsequent output operations.

.OVER **b** **---**

Depending on on current Graphics Mode, set the current OVER attribute for any subsequent output operations.

.PAPER **b** **---**

Depending on on current Graphics Mode, set the current PAPER color for any subsequent output operations.

3.3 DIR and LED – the Large file Editor and

Source text-files can be edited directly within vForth environment using **LED** – the Large file EDitor – that handles text files up to 17.568 rows, 85 characters each. The **LED** definition is available after you type: **NEEDS LED** .

LED asks NextZXOS for as many 8K-pages are needed to keep the text file in RAM, and an "Out-of-memory" error is issued if a page is not available, for instance because you already used some BANK command from Basic.

Along with **LED** you often need **DIR**.

After you type **LED** you enter a simple full-screen editor that can modify current file one screen at a time. While within **LED**, you are allowed move to next page or to previous page using the command explained below.

Remember: to ***quit*** **LED** editor, you have to use [**Edit**] key followed by [**Q**] key.

Remember: to ***save*** the file, you have to use [**Edit**] key followed by [**W**] key.

This editor works only while the display-mode is **LAYER 1,2**.

CD ---

Available after **NEEDS CD**. Change current directory. Used in the form

CD xxx

Warning : changing to a different directory impede any subsequent use of **NEEDS** until current directory is restored to its default.

DIR ---

Available after **NEEDS DIR**. Used in the form

DIR xxx

it displays the content of directory **xxx** for example: **DIR dev**

During display, [EDIT] key suspends output until the key is released.

```
ok
dir dev
.                                2023-02-18  22:19  d
..                               2023-02-18  22:19  d
HPVOC.F                          2023-03-13  23:45       5003
MARKER.F                         2023-03-12  16:58       1213
FORGET.F                         2023-03-12  01:27        724
id..f                            2023-02-27  22:50        232
words.f                                                   348
ok
■
```

LED --- cccc

Available after **NEEDS LED**. Used in the form

LED cccc

opens specified file cccc and enters **LED** editor. For example **LED lib/dir.f**
This editor inherits most of its commands and behavior from the previously described **EDIT** editor except that is has 85 characters per line instead of 64. See previous paragraph (§3.1) for details..

Along **LED** command, some more sub-commands are available to better handle a text-file.

LED-EDIT ---

Used in the form

LED-EDIT

re-enters the **LED** editor after you quit it to continue editing the same file you previously opened that should still be in upper 8k RAM pages, provided you haven't corrupted its content in some way.

LED-SAVE ---

Used in the form

LED-SAVE

saves back the file you previously open in **LED** editor, using the current filename you already specified using **LED** or **LED-FILE**.

LED-FILE --- cccc

Used in the form

LED-FILE cccc

modify the filename that **LED-SAVE** will write to. This allow to save to a different filename.

PWD ---

Available after **NEEDS PWD**. Prints current directory.

TOUCH --- cccc

Used in the form

TOUCH cccc

Accept the followin string cccc as a filename and update file-timestamp. If the file doesn't exist, it's created at zero length.

UNLINK --- cccc

Used in the form

UNLINK cccc

Accept the following string as a filename and remove it from disk, Beware, there is no way to recovery.
At this moment, you must specify the drive e.g. **unlink c:dummy.f** and despite it could be deemed a bug, I keep this behavior to improve security and avoid unwanted destructive operations.

3.4 Mouse

An *interrupt-driven mouse facility* is made available via **NEEDS MOUSE** (which requires **INTERRUPTS** described in Chapter 3.5).

Sprite #0 image is made a white arrow shape with shadow; its definition is given directly in Forth code, as follows (this, by the way, shows how easily Forth language can perform such a task):

```
HEX  14 REG@ CONSTANT E3 \ Global Transparency Colour
:  "  00  C,  ;  \ Black
:  |  6D  C,  ;  \ Dark-Grey
:  v  B6  C,  ;  \ Light-Gray
:  M  FF  C,  ;  \ White
:  _  E3  C,  ;  \ Transparency

\ Semi-graphical mouse-face definition 10x8-pixels arrow
CREATE MOUSE-FACE
\ 0 1 2 3 4 5 6 7 8 9 A B C D E F \
\ ------------------------------- \
  M | " " _ _ _ _ _ _ _ _ _ _ _ _ \  0
  M M | " " _ _ _ _ _ _ _ _ _ _ _ \  1
  M M M | " " _ _ _ _ _ _ _ _ _ _ \  2
  M M M M | " " _ _ _ _ _ _ _ _ _ \  3
  M M M M M | " " _ _ _ _ _ _ _ _ \  4
  M M M M M M | " " _ _ _ _ _ _ _ \  5
  M M M M M M M | " " _ _ _ _ _ _ \  6
  M M M M M M M M | " " _ _ _ _ _ \  7
  M M M M M M M M M | " " _ _ _ _ \  8
  M M M M M M | " " " " " " _ _ _ \  9
  M M | v M M | " " " _ _ _ _ _ _ \  A
  M | " v M M v | " " _ _ _ _ _ _ \  B
  | " _ _ v M M | " " _ _ _ _ _ _ \  C
  _ _ _ _ v M M v | " " _ _ _ _ _ \  D
  _ _ _ _ _ M M v | " " _ _ _ _ _ \  E
  _ _ _ _ _ v v | " " " _ _ _ _ _ \  F
```

The mouse hardware is polled every 20ms (i.e. during interrupt) and data is processed as follows:

1. Three bytes of polled raw-data are collected and kept in *x-status*, *y-status* and *buttons-status*. Buttons status are provided by the two LSB of collected byte, where zero means "pressed".
2. Current raw-data is compared against the previous raw-data to determine some delta and, depending on the events, *delta-x*, *delta-y* and *delta-buttons* can be positive or negative
3. If *delta-x* or *delta-y* is non-zero, then compute new position, clipping within screen range.
4. If *delta-buttons* is non-zero, determines the following values:
   0 : no event
   1 : right button click-down
   2 : left button click-down
   4 : right button click-up
   8 : left button click-up

The mouse position and status can be read using the following definitions:

MOUSE-XY **--- n1 n2**

Returns the current mouse position in pixel

`n1` : vertical distance from top-left corner in pixel. Range is 0 – 319.
`n2` : horizontal distance from top-left corner in pixel. . Range is 0 – 255.

?MOUSE **--- f**

Returns a true-flag if there is a mouse-click event.

MOUSE **--- n**

Collects the current click-event status and reset it to zero. The event is reported as follows:

0 : no event
1 : right button click-down
2 : left button click-down
4 : right button click-up
8 : left button click-up

multiple events are added together.

3.5 Interrupt Service Routine

After you type **NEEDS INTERRUPTS** a few new definitions will be loaded in memory along with some low-level definitions that allow setting-up an Interrupt-Driven definition: The ISR must be a single definition suitably defined. This is a standard IM 2 interrupt routine implementation. In the future, I hope to be able to exploit the new Next's IM 2 interrupt vector mode. Programming an Interrupt Service Routine using Forth itself is tricky and if not correctly coded, it can impair the system or cause a system-crash. As said, this library still does not exploit the new ZX Spectrum Next interrupt vector, this will be soon implemented: this means that the all these definitions listed here below will go under a deep overhaul when I'll code it.

A Z80's maskable interrupt occurs every 20 ms (50 times per second), and when it occurs, a CALL to a specific routine is performed. In vForth we use IM 2 interrupt mode by preparing a 257 bytes vector-table at $6200, filled with $63, so that the interrupt service routine is located at $6363 to jump to the suitable code – i.e. the definition **ISR-SUB** – that makes possible to a Forth definition to be executed as interrupt.

First, **ISR-SUB** performs a RST $38 to fulfill the legacy ISR, then it must save the whole *Forth machine status* by pushing to stack the value of CPU registers and then saving Forth's Return-Stack-Pointer and Calculator-Stack-Pointer.
Second, it prepares Forth virtual registers (Calculator-Stack Pointer, Return-Stack-Pointer and Instruction-Pointer) to execute the xt contained in ISR-W variable, then a jump to the Inner-interpreter via JP (IX) is performed. Interrupts stay disabled during the execution of such a xt.

After the xt contained in **ISR-XT** is executed, the **ISR-RET** definition is executed restoring back the machine status by retrieving Calculator-Stack Pointer, Return-Stack-Pointer and Instruction-Pointer and then popping all CPU registers before returning from the interrupt routine and re-enabling interrupts.

It's worth to be noticed that, since an interrupt may occur in the middle of the execution of any part of Forth system, not everything can be performed within an interrupt service routine, and care must be put to avoid critical interference with the main program, such as trying to write the same **VARIABLE** or invoking peculiar definitions that are known to modify the code they're going to execute, such as **CASEON**, **CASEOFF**, or memory areas such as most Floating-Point operations.

ISR-OFF ---

Disable Interrupt Utility by restoring IM 1 and I register to its default $3F value.

ISR-XT xt ---

Variable that contains the xt of the definition that will be executed in background at each Interrupt. It is always followed by the execution of **ISR-RET** so that **ISR-XT** can be viewed as the pointer to an anonymous definition that contains two definitions: the *interrupt-service-routine* definition and the *return-from-interrupt* definition.

ISR-ON ---

Enable *Interrupt Service Utility*: This definition prepares “IM 2 Vector Table” at address $6200-$6300 filling it with all $63 and set Interrupt Mode 2, so that when an Interrupt is issued a CALL to address $6363 is performed.

At address $6363 is a jump to address of **ISR-SUB** body i.e. **[' ISR-SUB >BODY]** and it's used in the form

```
ISR-OFF
' <your-isr-word>  ISR-XT  !
ISR-ON
```

Then, **<your-isr-word>** is executed in background at each Interrupt.

During an Interrupt, Forth uses a separate Calculator Stack (4 bytes below current SP) and a separate Return Stack located at $6330. Care must be paid to avoid any critical interference with the normal *foreground* Forth execution.

Typical usage is to control some Sprite movement or poll *mouse* and *joystick*, some demos are available.

The following example keeps the display filled with evenly spaced dots in Layer 1,1 or Layer 1,2 modes.

```
: ISR-WORD

      $80 $57FF C!
      $5701 $5700 $0FF CMOVE>
      $5700 $4700 $100 CMOVE
      $4700 $4F00 $100 CMOVE
;
ISR-OFF
' ISR-WORD ISR-XT !
ISR-ON
```

ISR-EI ---

Low-level "enable interrupt". It actually executes an EI opcode.

ISR-DI ---

Low-level "disable interrupt". It actually executes a DI opcode.

ISR-IM1 ---

Low-level "interrupt mode 1". It actually executes an IM 1 opcode. This is the default *mode* for any ZX Spectrum.

INT-IM2 ---

Low-level "interrupt mode 2". It actually executes an IM 2 opcode. It relies on a "vector table" located

ISR-SYNC ---

Low-level "sync to video". It actually executes an HALT opcode to force the machine to wait until the next interrupt.

SETIREG b ---

Low level Z80 register I setting. It actually executes an LD I, A opcode.

ISR-RET ---

Low-level "return from interrupt" definition. It restores all registers and returns control to Forth foreground execution.

ISR-SUB ---

Low-level "interrupt service routine" definition. It saves all registers and gives control to `INT-XT` background definition execution. Interrupt SP is initialized at 4 bytes below current SP. Interrupt RP is initialized at $6330 and allows room for 14 cells.

3.6 Block Search and Locate Utility

This group of definitions allow you to look for text within the Screens / Blocks and are available after you type alternatively:

NEEDS LOCATE or
NEEDS GREP or
NEEDS BSEARCH or
NEEDS COMPARE

LOCATE ---

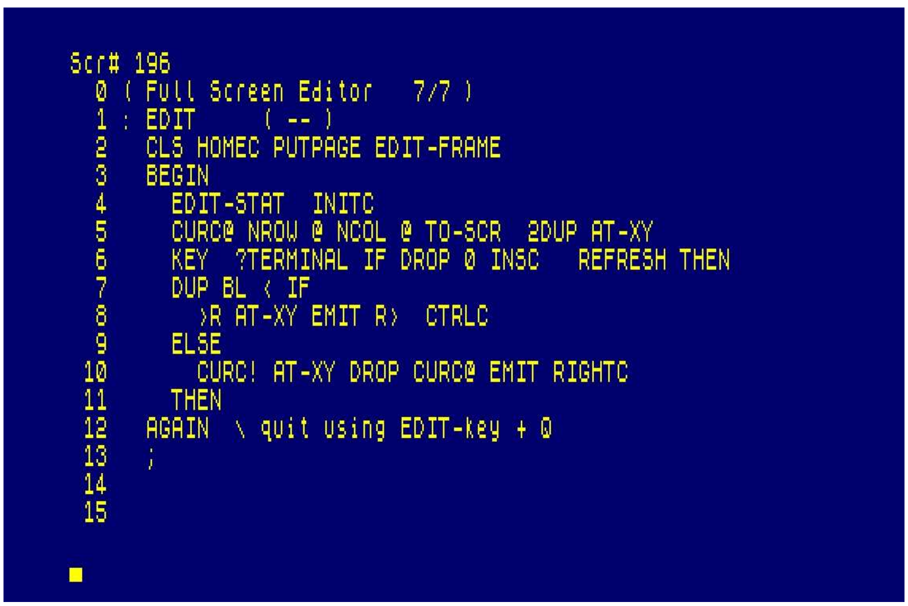
Used in the form

LOCATE cccc

this definition examines all Screens between 1 and 1000 looking for the definition of **cccc** showing the Screen where the first occurrence is found, then it makes it the “current screen”, just like **LIST** for example:

LOCATE EDIT

takes a few seconds to search in which Screen **COMPARE** is defined, and if found it shows the Screen using **LIST**.



GREP ---

Used in the form

GREP cccc

this definition examines all Screens between 1 and 2000 looking for any occurrence of string **cccc** showing them in a table form, for example

GREP EDIT

will take some more time to complete and gives something like the following

BSEARCH n1 n2 ---

Used in the form

n1 n2 BSEARCH cccc

this definition examines all Screens between n1 and n2 looking for any occurrence of definition **cccc** showing them in a table form. This definition is used by **GREP** that in fact is defined as **1 2000 BSEARCH** .

COMPARE a1 b1 a2 b2 ---

Given two string descriptors, that is address and length, (a1, b1) and (a2, b2), this definition compares the two strings and returns:

0	if they're equal
1	if String1 > String2
-1	if String1 < String2

For example:

```
CREATE S1 ," Hello world!"
CREATE S2 ," Hello world?"
S1 COUNT S2 COUNT COMPARE .
```

will print -1 since the two strings differs only for the last character and the ASCII code of ! comes before the code of ? , so the string comparison S1 < S2 is true. Compare the result of the following two rows:

```
S2 COUNT S1 COUNT COMPARE .
S1 COUNT S1 COUNT COMPARE .
```

CASEON and **CASEOFF** modify the behavior of **COMPARE** definition being case-sensitive or case-insensitive.

3.7 Debugger Utility

The following definitions are available after you type **NEEDS SEE** or usually after a regular **AUTOEXEC**.

Also, this section exposes in detail how definitions are stored in dictionary memory.

In the **Indirect-Threaded** version, low-level definitions CFA contains the address of PFA that in turn contains the actual definition machine code; in a colon definition the CFA points to the address of the routine that handles that kind of definition.

In **Direct-Threaded** version (version 1.7), a Low-Level definition takes two bytes less, since CFA directly contains the actual definition machine code; then a Colon-definition needs one additional byte in CFA to allow room for a “CALL” op-code to call the address that handles that kind of definition. This allows some 25% of more speed at the cost of using a little more memory used.

SEE ---

Used in the form

```
SEE cccc
```

it prints how definition cccc is defined along with its NFA, LFA, CFA, PFA information.

If cccc is a regular colon-definition, the result will show something very close to the original source code the definition was coded from.

For example, the definition **TYPE** is a colon-definition that emits to video an **n** bytes-long string stored at address **a**, and it's defined as follow:

```
: TYPE   ( a n -- )
    BOUNDS ?DO
        I C@ EMIT
    LOOP ;
```

If you type

```
SEE TYPE
```

the system will emit something like this:

```
Nfa: E7CD 84
Lfa: E7D2 7C3 LEAVE
Cfa: 6F83 6A3D
BOUNDS (?DO) 12 I C@ EMIT (LOOP) -8 EXIT ok
```

The first line shows **TYPE** **N**ame **F**ield **A**ddress (**$E7CD**) followed by **$84** that is the counter byte of a 4-bytes length name. The counter byte always has the most significant bit set, that is **$80** added to **$04** giving **$84**.

The second line is the **L**ink **F**ield **A**ddress (**$E7D2**) which holds a *heap-pointer* **$07C3** to **LEAVE**’s NFA that in this case happens to be the previous definition in the dictionary.

You will notice these two fields (NFA and LFA) are stored above address $E000 (i.e. MMU7) and they are effectively stored in one of the extended 8K-RAM pages.

The third line is the **C**ode **F**ield **A**ddress (**$6F83**) that contains the actual machine code to be run which in this case is a

"CALL" to the ENTER routine of every colon-definition, located at **$6A3D**.

The fourth line represents the **P**arameter **F**ield **A**ddress and, in this case, is in some way a definition *decompilation* but literals and offsets are shown in "inverse video". For example the number **-8** after **(LOOP)** is the "offset" to where the Instruction Pointer has to jump to go back to next iteration, that is 4 cells backward. In this example **(?DO)** and **(LOOP)** are the *compiled counterpart* of **?DO** and **LOOP** that in fact normally won't be *compiled,* instead they control the compilation of some other definitions.

Another example, the definition **NIP** that removes the second element from Stack, isn't a colon-definition, but a low-level definition coded directly in machine-code as follow:

```
CODE NIP   ( n1 n2 -- n2 )
        POP       HL|     \  pop  hl
        EX(SP)HL          \  ex   (sp), hl
        Next              \  jp   (ix)
        C;
```

and if you type

```
SEE NIP
```

you'll see

```
Nfa: E2F1 83
Lfa: E2F5 2E8 DROP
Cfa: 6914 DDE3
6915 E1 E3 DD E9  00 03 E1 F1  ac]i  aq
```

In this case, since **NIP** is a low-level definition, the PFA part is shown as a hexadecimal **DUMP** that is it has no PFA part, but it's a real machine-code routine.

Again, the first line shows **NIP**'s NFA (**$E2F1** in this case) and **$83**, the counter byte, that indicates a 3-bytes length definition name.
The second line is **NIP**'s LFA (**$E2F5**) that contains a *heap-pointer* **02E8** to **DROP**'s NFA, that is the previous definition in dictionary.
The third line is **NIP**'s CFA (**$6914**) which content contains the machine-code routine itself.
Examining the subsequent **DUMP** you should be able to locate **E1** for POP HL, **E3** for EX(SP),HL and **DD E9** for JP(IX) to the inner interpreter address that is compiled by **NEXT** Assembler definition (§3.10).
The bytes that follows – **00 03 E1 F1** – are the beginning of the subsequent definition compiled in dictionary (**TUCK** in this case). This utility is not perfect, but is a good way to debug and understand a Forth definition.

Last example is the definition **IF** a colon-definition that compiles a conditional branching in the program flow, defined as follows:

```
: IF     ( -- a 2 ) \ compile-time
    COMPILE 0BRANCH
    HERE 0 , 2 ; IMMEDIATE
```

with the following output:

```
Nfa: EC92 C2
Lfa: EC95 C89 BACK
Cfa: 8032 6A3D
COMPILE  0BRANCH  HERE 0 , 2 EXIT ok
```

In this case, since **IF** is an **IMMEDIATE** definition, the NFA length-byte is **$C2** instead **$82**.

3.7.1 The Inner-interpreter

At the very core level of any Forth system lies the *Inner Interpreter*, that needs a few information to keep the system itself alive, namely the *Instruction Pointer*, the *Calculator Stack Pointer* and the *Return Stack Pointer*.

The latest version of vForth keeps such fundamental status information in some permanently dedicated Z80 registers:

- **BC** The *Instruction Pointer* that points to the current "xt" being executed
- **SP** the *Data Stack Pointer* that points to the "top-of-stack"
- **DE** the *Return Stack Pointer* used to keep some value of IP and used to track sub-routines calls
- **IX** the address of the *Inner Interpreter* routine, aka "NEXT".

Any other register, such as A, F, H, L and all alternate registers A', F', B', C', D', E', H', L', are free to be used by the low-level definitions.

```
NEXT:
    ld      a, (bc) ; fetch the xt pointed by Instruction Pointer (bc).
    inc     bc
    ld      l, a
    ld      a, (bc)
    inc     bc      ; IP is incremented to point the following xt.
    ld      h, a
    jp      (hl)    ; jump to xt address also known as "CFA"
```

```
CFA:                ; "CFA" contains the actual machine-code to be executed
    call    ENTER   ; and it can be simply a CALL to the piece of code peculiar
                    ; to that kind of definition.
                    ; For example a "colon-definition" has a CALL to ENTER
PFA: ...
```

```
ENTER:
    ex      de, hl  ; bring Return Stack Pointer (de) to hl register
    ld      (hl), b ; and save the current value of Instruction Pointer (bc)
    inc     hl
    ld      (hl), c
    inc     hl
    ex      de, hl  ;
    pop     bc      ; Instruction Pointer now contains PFA
    jp      (ix)    ; jump back to NEXT
```

DUMP **a u ---**

Performs a "dump" of a memory area from address `a` for `u` bytes or until **[Break]** is pressed. The value of `u` is always rounded to the nearest greater multiple of 8.

Visualization is always in hexadecimal, current base is maintained. For example:

```
DECIMAL 448 60 DUMP
```

will print the Standard ROM content starting from address 448 ($01C0) for 64 bytes, i.e. the nearest greater multiple of 8 and keeps **DECIMAL** as the current **BASE**.

```
01C0  4C 49 53 D4  4C 45 D4 50  LISTLETP
01C8  41 55 53 C5  4E 45 58 D4  AUSENEXT
01D0  50 4F 4B C5  50 52 49 4E  POKEPRIN
01D8  D4 50 4C 4F  D4 52 55 CE  TPLOTRUN
01E0  53 41 56 C5  52 41 4E 44  SAVERAND
01E8  4F 4D 49 5A  C5 49 C6 43  OMIZEIFC
01F0  4C D3 44 52  41 D7 43 4C  LSDRAWCL
01F8  45 41 D2 52  45 54 55 52  EARRETUR
```

.WORD a ---

Given a CFA, this definition prints the **ID.** It is used by **SEE** to perform some "decompilation".

.S ---

Prints the current content of Calculator Stack without destroying its content.
For example, supposing to start with an empty stack,

```
0 1 2 3 .S
```

will print

```
0 1 2 3 ok
```

DEPTH --- n

It leaves the depth of the Calculator Stack before it was executed. For example, supposing to start with an empty stack,

```
0 1 2 DEPTH .
```

will print

```
3 ok
```

3.8 Floating-Point Option

This is an simple Floating-Point Option Library that exploits the native standard ZX Spectrum Floating-Point capabilities, with some differences. This library is not yet compatible with DOT-command version.

To load this Floating-point Option Library you have to use **`NEEDS FLOATING`**.

To perform any floating-point operations you first need to push one or two numbers onto *Spectrum's calculator stack* using **`>W`** definition. then you need to call the floating-point calculator using **`FOP`** definition (that calls RST $28 service routine). Finally, you have to pop the result from Spectrum's calculator stack using **`W>`** definition.

For example, to define a definition that returns the value of *pi* you can code something like this:

```
: PI
  [  1 0 >W 36 FOP  \ atan(1)
     4 0 >W 04 FOP  \ *4
     W>  ]  DLITERAL
;
```

A floating point in Spectrum's calculator stack takes 5 bytes, instead in Forth Calculator Stack it takes 4 bytes only i.e. the same as a “double-integer”. This means there is some **precision loss**: Maybe in the future I'll be able to fix this fact.

Thinking the floating-double-number stored in CPU registers HLDE, the sign is the msb of H, so you can check for sign in the integer-way. The exponent+128 is stored in the following 8 bits of HL and the significand/mantissa is stored the remaining bits of HL and 16 bits of DE. The fifth byte of a standard floating-point number is then defaulted to a fixed value.

If the floating-number is an integer between 0 and 65535, then it is kept on stack the same as a double-integer. To verify this fact you can type.

```
FLOATING  DECIMAL  65535.0  65537.0  .S
```

that displays

```
65535  0   128  18560
```

where the two single precision integer 65535 and 0 are the representation of 65535.0 while the two integers 128 and 18560 are the internal bit-representation of 65537.0

The integer on TOS always keeps the sign information of the floating-double-number.

Most of the definitions described below are created using **`<BUILDS DOES>`** technique.

3.8.1 Floating-point option activation and number conversion

To import the floating point library option you must type **`NEEDS FLOATING`** and then, you can use **`FLOATING`** to enable the floating-number interpretation and **`INTEGER`** to disable it and remain within the integers.

INTEGER ---

Deactivate floating-point numbers mode. **`NMODE`** user variable is set to 0.

FLOATING ---

Activate floating-point numbers mode. **NMODE** user variable is set to 1.

D>F d --- fp

Convert a double-integer into a floating-double-number. See **F>D**.

F>D fp --- d

Convert a floating-double-number into a double-integer truncating to the lower integer. It's the opposite of **D>F**.

FLOAT n --- fp

Convert a single-precision-integer into a floating-double-number. See **FIX.**

FIX fp --- n

Convert a floating-double-number a into single-precision-integer. It's the opposite of **FLOAT.**

3.8.2 Representation and constants

F>PAD fp --- u

The representation of floating-double-number fp is stored in **PAD**. The number u is the length of the string.

F.R fp u ---

Prints fp on a field of u characters to video or current stream (See **SELECT**).

F. fp ---

Prints fp to video or current stream (See **SELECT**).

1/2 --- fp

Put on TOS the value 0.5.

PI --- fp

Put on TOS the value of pi.

3.8.3 Arithmetics

F- fp1 fp2 --- fp3

Floating point difference: fp3 := fp1 – fp2

F+ fp1 fp2 --- fp3

Floating point addition: fp3 := fp1 + fp2

F* **fp1 fp2 --- fp3**
Floating point product: fp3 := fp1 * fp2

F/ **fp1 fp2 --- fp3**
Floating point division: fp3 := fp1 / fp2

FNEGATE **fp1 --- fp2**
Floating point negate, i.e. : fp1 := - fp2

FSGN **fp1 --- fp2**
Floating point sign. Fp2 is the sign of fp1.

FABS **fp1 --- fp2**
Floating point absolute value

F/MOD **fp1 fp2 --- fp3 fp4**
Floating point division and reminder: fp4 is the quotient of fp1 / fp2 and fp3 is the reminder.

F** **fp1 fp2 --- fp3**
Floating point power: fp3 := fp1 ^ fp2

FMOD **fp1 fp2 --- fp3**
Floating point module: fp3 := fp1 mod fp2

F*/ **fp1 fp2 fp3 --- fp4**
Floating point scale operation: fp4 := fp1 * fp2 / fp3 using an intermediate precision of native 5 bytes instead of 4.

F< **fp1 fp2 --- f**
Floating point comparison: f is TRUE if fp1 < fp2, FALSE otherwise.

F> **fp1 fp2 --- fp3**
Floating point comparison: f is TRUE if fp1 > fp2, FALSE otherwise.

F0< **fp1 --- f**
Floating point comparison: f is TRUE if fp1 < 0, FALSE otherwise.

F0> **fp1 --- f**
Floating point comparison: f is TRUE if fp1 > 0, FALSE otherwise.

3.8.4 Log, Exp, Trig

FLN **fp1 --- fp2**

Floating point Natural Logarithm. fp2 := ln(fp1)

FEXP **fp1 --- fp2**

Floating point Exponentation: fp2 := exp(fp1)

FINT **fp1 --- fp2**

Integer truncation. If the floating-double-number is an integer between 0 and 65535, then it is kept on stack the same as a double-integer. **1.4 FINT** gives 1.0 but **-1.4 FINT** gives -2.0

FSQRT **fp1 --- fp2**

Square root.

FSIN **fp1 --- fp2**

Sine in radians.

FCOS **fp1 --- fp2**

Cosine in radians.

FTAN **fp1 --- fp2**

Tangent in radians

FASIN **fp1 --- fp2**

Arc-sine in radians

FACOS **fp1 --- fp2**

Arc-cosine in radians

FATAN **fp1 --- fp2**

Arc-tangent in radians.

RAD>DEG **fp1 --- fp2**

Convert radians to degrees.

DEG>RAD **fp1 --- fp2**

Convert degrees to radians.

3.8.5 Low-level definitions.

FOP **n** **---**

Low-level definition that invokes Floating-Point-Operation n .

>W **fp** **---**

Takes a floating-point number d from Calculator Stack and put to Floating-Pointer Stack.

W> **fp** **---**

Takes a floating-point number d from Calculator Stack and put to Floating-Pointer Stack.

3.9 Line Editor

The following definitions are available after you include the **EDITOR** vocabulary via **NEEDS EDITOR** or **90 LOAD** using the old fashion way. Most of the logic shown in this section is used by **LED** "The Large file Editor".

The Line Editor has a dozen definitions that can operate on a single line of a given Screen and helps inspect things around.

An edit session normally starts with a **LIST** on the desired Screen, this sets `SCR` user variable to the passed Screen number. **LIST** is a definition already available in the "core" dictionary. To clear a Screen I foreseen a **BCLEAR** definition, but I left it commented somewehere for now, deeming it too dangerous for my tastes; instead I usually use **BCOPY** from an actually empty Screen. You may type **NEEDS BCOPY.**

The definition **FLUSH** flushes to disk any modification you've done on any Screen. Beware, a Screen is re-written to disk as soon as the **BUFFERS** containing it are modified. To save space, this implementation has 7 **BUFFER**s**.**

EMPTY-BUFFERS is another vital definition: it empties all buffers. It is very useful if you mistakenly overwrite or spoil a Screen during an edit operation, with it, you have the chance to "rollback" the things before anything is written to disk.

To write a line from scratch or to overwrite line, you can use `P` to "put" the following text to the given line on current screen. For example:

```
1000 LIST
0 P \ One thousand screens
L
```

This sequence selects Screen# 1,000 and put a text "\ One thousand screens" on the first line of it. The definition `L` repeats the `LIST` of current screen.

To move or copy a line around, you can use `H` to "hold in `PAD`" a given line on current screen, you can change Screen if you wish, then you can complete this **copy-and-paste** operation with `INS` to "insert" or `RE` to "replace" the line you copied in advance with H. None of above definitions, but `H`, modify PAD content, so you can repeat the operation. There is also a way to **cut-and-paste** a line using `D` to "delete and copy to `PAD`" instead of `H`.

See also **BLOCK**, **BUFFER**, **INDEX**, **L/SCR**, **LIST**, **LOAD**, **MESSAGE**, **PAD**, **SCR**, **STRM**, **TIB.**

This is a quick reference of involved memory areas and definitions that work on them.

Text Input Buffer (keyboard) **TIB**	Parsing Operation	**PAD**	Edit Operations	One **BLOCK BUFFER**	Blanking Operations
	TEXT →		← **H** **RE** →		← **E**
			← **D** **INS** →		← **S**
			P →		

-MOVE **a n** **---**

"Line move". It moves a line, **C/L** bytes length, from address a to the line n of current screen, then it does an **UPDATE**. Current Screen is the one kept by **SCR**.

.PAD **---**

"Show PAD". It prints the current **PAD** content assuming it contains a counted-string.

B **---**

"Back" one Screen. This definition set to previous Screen by decreasing **SCR** and prints it using **LIST**.

D **n** **---**

"Delete" a row. It deletes line n of current Screen (the one indicated by **SCR**) , the following lines are moved up and the last one will be blanked. D executes H so that it can be followed by an **INS** to perform a line move.

BCOPY **n1 n2** **---**

"Block-Copy" utility that copies Screen n1 to Screen n2. **SCR** will contain n2. This definition's standard name is **COPY**, but I deemed too close to the Basic keyword **COPY**.

E **n** **---**

"Erase" a row. This definition fills line n with spaces. It does **UPDATE**.

H **n** **---**

"Hold" a row in **PAD**. This definition put line n of current Screen to PAD without altering the block on disk. Current Screen is the one kept in **SCR**.

INS **n** **---**

"Insert" from **PAD**. This definition inserts line n using text in **PAD**. The original line n and the following ones are moved down and the last is lost.

L **---**

"List" current Screen. This definition does **SCR @ LIST**.

LINE **n** **--- a**

Leaves the address a of line n of current screen, the one kept in **SCR**. Such a screen is currently held in a buffer.

N **---**

"Next" Screen. This definition sets to next Screen by increasing **SCR** and prints it using **LIST**.

P **n** **---**

"Put" a line. This definition accepts the following text (delimited by a tilde character ~) as the text of line n of current

Screen. Text is taken from **TIB** and sent to the current Screen

RE n ---

"Replace". This definition takes text currently in **PAD** and put it to line n.

S n ---

"Space" one row. This definition frees line n moving the following lines down by one. The last line is lost

SAVE ---

Does **UPDATE** and **FLUSH** saving this Screen and all previously modified Screens back to disk.

ROOM ---

This definition shows the room available in the dictionary, that is the difference between **SP@** and **PAD** addresses.

TEXT c ---

This definition accepts the following text and stores it to **PAD**. c is a text delimiter. **TEXT** does not go beyond a 0x00 [null] ASCII.

UNUSED --- n

It returns the number of byte available in dictionary.

WHERE n1 n2 ---

Usually executed after an error has been reported during a **LOAD** session. Maybe, this definition should be included in "core" dictionary. n1 is the value of IN and n2 the value of **BLK** as were left by **ERROR**.
WHERE shows on screen the block number, the line number, the very same line highlighting in "inverse video" the definition that caused the error.
If it is invoked after an error during the loading via **NEEDS** or **INCLUDE**, then the result is a bit poor, because it always reports the row #8 of block #1 due to the way these two definitions are coded.

WIPE ---

Set content of current Screen to blanks.

3.10 ASSEMBLER vocabulary

The following definitions are available after you type **100 LOAD** or after you include the **ASSEMBLER** vocabulary via **NEEDS ASSEMBLER**. Then, you can list this vocabulary using **ASSEMBLER WORDS**.

This is a Zilog Z80 adaptation of an Intel 8080 assembler written by Albert van der Horst available at https://github.com/albertvanderhorst/ciasdis.

To create a new definition using this Assembler you have to use **CODE**. Compilation **STATE** is never modified, so usually you assemble things while in interpret **STATE**. Usually, a **CODE** definition should end with **NEXT** that compiles a **jp (ix)** op-code. Finally **C;** makes the new definition available for subsequent search.

Between the starting **CODE** and the ending **C;** instructions are given using their specific op-codes followed by as many parameters as needed.

The following table describes all type of arguments used by the op-code list below:

rr|	:	BC|	DE|	HL|	SP|	and when the case		IX|	IY|	and	AF|	
r|	:	B|	C|	D|	E|	H|	L|	A|	and	(HL)|		**{ source registers }**
r'|	:	B'|	C'|	D'|	E'|	H'|	L'|	A'|	and	(HL)'|		**{ destination registers }**
f|	:	NZ|	Z|	NC|	CY|	PO|	PE|	P|	M|	**{ flags used by JP, CALL and RET }**		
f'|	:	NZ'|	Z'|	NC'|	CY'|	**{ same as f| above but used by JR }**						
b|	:	0|	1|	2|	3|	4|	5|	6|	7|		**{ bit number operand }**	
a|	:	00|	08|	10|	18|	20|	28|	30|	38|			
d	:	byte displacement	**{ used by JR }**									
n	:	byte value (8 bits)										
nn	:	integer value (16 bits)										
aa	:	address										
r	:	Next hardware-register number										

Other peculiarity are

CY| and **CY'|**	to specify "carry-flag" to be different from **C|** or **C'|** "register".
(IX+ and **(IY+**	to begin a "index-register" argument and)| to close it.
(IX'+ and **(IY'+**	same as above, but for destination argument.

You can use **(IY+** operand wherever you can use **(IX+** operand.

3.10.1 Complete list of Assembler Op-Code

Here's the correspondence between Forth and original Z80 mnemonic, Z80N in **red** font.

FORTH ASSEMBLER	Z80 MNEMONIC
ADCA (HL)|	ADC A, (HL)
ADCA (IY+ d)|	ADC A, (IY+d)
ADCN n N,	ADC A, n
ADCA r|	ADC A, r
ADCHL rr|	ADC HL, BC/DE/HL/SP
ADDA (HL)|	ADD A, (HL)
ADDA (IY+ d)|	ADD A, (IY+d)
ADDN n N,	ADD A, n
ADDA r|	ADD A, r
ADDHL rr|	ADD HL, BC/DE/HL/SP
ADDHL,A	**ADD HL, A**
ADDDE,A	**ADD DE, A**
ADDBC,A	**ADD BC, A**
ADDHL, nn NN,	**ADD HL, nn**
ADDDE, nn NN,	**ADD DE, nn**
ADDBC, nn NN,	**ADD BC, nn**
ADDIY rr|	ADD IY, BC/DE/IY/SP
ANDA (HL)|	AND (HL)
ANDA (IY+ d)|	AND (IY+d)
ANDN n N,	AND n
ANDA r|	AND r
BIT b| (HL)|	BIT b, (HL)
BIT b| (IY+ d)|	BIT b, (IY+d)
BIT b| r|	BIT b, r
BRLCDE,B	**BRLC DE, B**
BSLADE,B	**BSLA DE, B**
BSRADE,B	**BSRA DE, B**
BSRFDE,B	**BSRF DE, B**
BSRLDE,B	**BSRL DE, B**
CALLF f| aa AA,	CALL Z/NZ/C/NC/PO/PE/P/M, aa
CALL aa AA,	CALL aa
CCF	CCF
CPA (HL)|	CP (HL)
CPA (IY+ d)|	CP (IY+d)
CPN n N,	CP n
CPA r|	CP r
CPD	CPD
CPDR	CPDR
CPI	CPI
CPIR	CPIR
CPL	CPL
DAA	DAA
DEC (HL)'|	DEC (HL)
DEC (IY'+ d)|	DEC (IY+d)
DECX rr|	DEC BC/DE/HL/SP
DECX IX|	DEC IX
DECX IY|	DEC IY
DEC r'|	DEC r
DI	DI
DJNZ d D,	DJNZ d
EI	EI
EX(SP)HL	EX (SP), HL

EX(SP)IY	EX (SP), IY
EXAFAF	EX AF, A'F'
EXDEHL	EX DE, HL
EXX	EXX
HALT	HALT
IM0	IM 0
IM1	IM 1
IM2	IM 2
IN(C) (HL)'|	IN (c)
INA n P,	IN A, (n)
IN(C) r'|	IN r, (c)
INC (HL)'|	INC (HL)
INC (IY'+ d)|	INC (IY+d)
INCX rr|	INC BC/DE/HL/SP
INCX IX|	INC IX
INCX IY|	INC IY
INC r'|	INC r
IND	IND
INDR	INDR
INI	INI
INIR	INIR
JP(C)	**JP (C)**
JPHL	JP (HL)
JPIX	JP (IX)
JPIY	JP (IY)
JPF f| aa AA,	JP Z/NZ/NC/C/PO/PE/P/M, aa
JP aa AA,	JP aa
JRF f'| d D,	JR C/NC/Z/NZ, d
JR d D,	JR d
LD(X)A rr|	LD (BC/DE), A
LD (HL)'| r|	LD (HL), n
LDN (HL)'| n N,	LD (HL), r
LDN (IY'+ d)| n N,	LD (IY+d), n
LD(IY+ d)| r|	LD (IY+d), r
LD()A aa AA,	LD (nn), A
LD()X rr| nn AA,	LD (nn), BC/DE/SP
LD()IY aa AA,	LD (nn), IY
LD()HL aa AA,	LD (nn), HL
LDA(X) rr|	LD A, (BC/DE)
LDA() aa AA,	LD A, (aa)
LDAI	LD A, I
LDAR	LD A, R
LDX rr| nn NN,	LD BC/DE/HL/SP, nn
LDX() rr| nn AA,	LD BC/DE/SP/IY, (aa)
LDHL() aa AA,	LD HL, (aa)
LDIA	LD I, A
LDX IY| nn NN,	LD IY, nn
LDRA	LD R, A
LDSPHL	LD SP, HL
LDSPIX	LD SP, IX
LDSPIY	LD SP, IY
LD r'| (HL)|	LD r, (HL)
LD r'| (IY+ d)|	LD r, (IY+d)
LD r'| r|	LD r, r
LDN r'| n N,	LD r, n
LDD	LDD
LDDR	LDDR
LDDRX	**LDDRX**
LDDX	**LDDX**
LDI	LDI
LDIR	LDIR

<table>
<tr><td>LDIRX</td><td>**LDIRX**</td></tr>
<tr><td>LDIX</td><td>**LDIX**</td></tr>
<tr><td>LDPIRX</td><td>**LDPIRX**</td></tr>
<tr><td>LDWS</td><td>**LDWS**</td></tr>
<tr><td>MIRRORA</td><td>**MIRROR A**</td></tr>
<tr><td>MUL</td><td>**MUL**</td></tr>
<tr><td>NEG</td><td>NEG</td></tr>
<tr><td>NEXTREGA r P,</td><td>**NEXTREG r, A**</td></tr>
<tr><td>NEXTREG r P, n N,</td><td>**NEXTREG r, n**</td></tr>
<tr><td>NOP</td><td>NOP</td></tr>
<tr><td>ORA (HL)|</td><td>OR (HL)</td></tr>
<tr><td>ORA (IY+ d)|</td><td>OR (IY+d)</td></tr>
<tr><td>ORN n N,</td><td>OR n</td></tr>
<tr><td>ORA r|</td><td>OR r</td></tr>
<tr><td>OTDR</td><td>OTDR</td></tr>
<tr><td>OTIR</td><td>OTIR</td></tr>
<tr><td>OUT(C) (HL)'|</td><td>OUT (c), 0</td></tr>
<tr><td>OUT(C) r'|</td><td>OUT (c), r</td></tr>
<tr><td>OUTA n P,</td><td>OUT (n), A</td></tr>
<tr><td>OUTD</td><td>OUTD</td></tr>
<tr><td>OUTI</td><td>OUTI</td></tr>
<tr><td>OUTINB</td><td>**OUTINB**</td></tr>
<tr><td>PIXELAD</td><td>**PIXELAD**</td></tr>
<tr><td>PIXELDN</td><td>**PIXELDN**</td></tr>
<tr><td>POP AF|</td><td>POP AF</td></tr>
<tr><td>POP rr|</td><td>POP BC/DE/HL</td></tr>
<tr><td>POP IX|</td><td>POP IX</td></tr>
<tr><td>POP IY|</td><td>POP IY</td></tr>
<tr><td>PUSH rr|</td><td>PUSH BC/DE/HL/AF</td></tr>
<tr><td>PUSH IX|</td><td>PUSH IX</td></tr>
<tr><td>PUSH IY|</td><td>PUSH IY</td></tr>
<tr><td>PUSHN nn LH,</td><td>**PUSH nn**</td></tr>
<tr><td>RES b| (HL)|</td><td>RES b, (HL)</td></tr>
<tr><td>RES b| (IY+ d)|</td><td>RES b, (IY+d)</td></tr>
<tr><td>RES b| r|</td><td>RES b, r</td></tr>
<tr><td>RES b| r| (IY+ d)|</td><td>RES r, b, (IY+d)</td></tr>
<tr><td>RET</td><td>RET</td></tr>
<tr><td>RETF f|</td><td>RET Z/NZ/C/NC/PO/PE/P/M</td></tr>
<tr><td>RETI</td><td>RETI</td></tr>
<tr><td>RETN</td><td>RETN</td></tr>
<tr><td>RL (HL)|</td><td>RL (HL)</td></tr>
<tr><td>RL (IY+ d)|</td><td>RL (IY+d)</td></tr>
<tr><td>RL r|</td><td>RL r</td></tr>
<tr><td>RL r| (IY+ d)|</td><td>RL r, (IY+d)</td></tr>
<tr><td>RLA</td><td>RLA</td></tr>
<tr><td>RLC (HL)|</td><td>RLC (HL)</td></tr>
<tr><td>RLC (IY+ d)|</td><td>RLC (IY+d)</td></tr>
<tr><td>RLC r|</td><td>RLC r</td></tr>
<tr><td>RLC r| (IY+ d)|</td><td>RLC r, (IY+d)</td></tr>
<tr><td>RLCA</td><td>RLCA</td></tr>
<tr><td>RLD</td><td>RLD</td></tr>
<tr><td>RR (HL)|</td><td>RR (HL)</td></tr>
<tr><td>RR (IY+ d)|</td><td>RR (IY+d)</td></tr>
<tr><td>RR r|</td><td>RR r</td></tr>
<tr><td>RR r| (IY+ d)|</td><td>RR r, (IY+d)</td></tr>
<tr><td>RRA</td><td>RRA</td></tr>
<tr><td>RRC (HL)|</td><td>RRC (HL)</td></tr>
<tr><td>RRC (IY+ d)|</td><td>RRC (IY+d)</td></tr>
<tr><td>RRC r|</td><td>RRC r</td></tr>
<tr><td>RRC r| (IY+ d)|</td><td>RRC r,(IY+d)</td></tr>
<tr><td>RRCA</td><td>RRCA</td></tr>
</table>

`RRD`	`RRD`
`RST a|`	`RST n`
`SBCA (HL)|`	`SBC A, (HL)`
`SBCA (IY+ d )|`	`SBC A, (IY+d)`
`SBCN n N,`	`SBC A, n`
`SBCA r|`	`SBC A, r`
`SBCHL rr|`	`SBC HL, BC/DE/HL/SP`
`SCF`	`SCF`
`SET b| (HL)|`	`SET b, (HL)`
`SET b| (IY+ d )|`	`SET b, (IY+d)`
`SET b| r|`	`SET b, r`
`SET b| r| (IY+ d )|`	`SET r, b, (IX+d)`
`SETAE`	**`SETAE`**
`SL1 (HL)|`	`SL1 (HL)`
`SL1 (IY+ d )|`	`SL1 (IY+d)`
`SL1 r|`	`SL1 r`
`SL1 r| (IY+ d )|`	`SL1 r, (IY+d)`
`SLA (HL)|`	`SLA (HL)`
`SLA (IY+ d )|`	`SLA (IY+d)`
`SLA r|`	`SLA r`
`SLA r| (IY+ d )|`	`SLA r, (IY+d)`
`SRA (HL)|`	`SRA (HL)`
`SRA (IY+ d )|`	`SRA (IY+d)`
`SRA r|`	`SRA r`
`SRA r| (IY+ d )|`	`SRA r, (IY+d)`
`SRL (HL)|`	`SRL (HL)`
`SRL (IY+ d )|`	`SRL (IY+d)`
`SRL r|`	`SRL r`
`SRL r| (IY+ d )|`	`SRL r, (IY+d)`
`SUBA (HL)|`	`SUB (HL)`
`SUBA (IY+ d )|`	`SUB (IY+d)`
`SUBN n N,`	`SUB n`
`SUBA r|`	`SUB r`
`SWAPNIB`	**`SWAPNIB`**
`TESTN n N,`	**`TEST n`**
`XORA (HL)|`	`XOR (HL)`
`XORA (IY+ d )|`	`XOR (IY+d)`
`XORN n N,`	`XOR n`
`XORA r|`	`XOR r`

The COMMAER's are definitions that enforce some syntax-error checking while assembling op-codes parameters.

- `N,` immediate single byte value.
- `NN,` immediate 16 bits value.
- `AA,` memory address value.
- `P,` port address value (16 bits) and, in NEXTREG op-code, Next's hardware-register number.
- `D,` displacement in relative jump JR.
- `LH,` used by Next's PUSHN to compile big-endian 16-bits argument.

Some single byte op-code was renamed to have a better near-Z80 notation. To avoid some Forth-Assembler name clash, it is preferred using some peculiar notation, for example **`EXAFAF EX(SP)HL EXDEHL`** instead of EX AF, AF' or EX (SP),HL or EX DE,HL. Also, we explicitly say A for all arithmetic/logic opcodes, e.g. **`ANDA r|`** instead of AND r and so on. IX and IY index-register cause most trouble because they add both a prefix and a displacement and because they can be used in conjunction with CB prefix. In this case we use some custom late-compilation definitions to fix things but relaxing some of the syntax check that the Albert's core provided. Z80N extensions are all ED-prefixed, so the follow the same way introducing a new **`LH,`** COMMAER to enforce a better syntax check.

Here are a few examples:

3.10.2 Assembler Example - Checksum

This definition calculates the checksum of addresses between `a` and `a+u` inclusive. The algoritm simply adds each byte (mod 256).

```
NEEDS ASSEMBLER
CODE CHECKSUM ( a u -- b )
      exx                  \ needs this to preserve BC and DE
      pop     bc|          \ counter
      pop     hl|          \ start address
      xora     a|          \ zero to accumulator
HERE  adda  (hl)|,         \ add mod 256
      cpi                  \ increment HL, decrement BC
      jpf     pe|  AA,     \ loop back if BC is not zero
      ld      c'|   a|
      push    bc|          \ return result
      exx                  \ restore register BC and DE
      NEXT
C;                         \ this performs SMUDGE
```

Up to now, there is no labels, since the same functionality is given by a clever use of `HERE` and stack manipulation, and because routines are kept short.

For example:

```
DECIMAL 12 256 CHECKSUM .
94 ok
```

3.10.3 Assembler Example - WHITE-NOISE from Egghead 3

This is an example taken from "Egghead 3" that uses the first bytes of ROM as a pseudo-random number list used to produce a white noise.

Labels are a little more obsure, but each `HERE` is resolved without confusion using **`BACK,`**

Also, this is an example of *forward reference* resolved directly patching the code just compiled: the address the subroutine is patched by saving the instruction address (the first `HERE`) and then using the sequence `HERE SWAP 1+ !` to patch the previous CALL.

```
NEEDS ASSEMBLER
DECIMAL
CODE WHITE-NOISE ( -- )
      di
      exx
HERE  call  0000  AA,          \ 0000 is patched here below (*)
      exx
      ei
      next

\ subroutine
HERE  SWAP  1+  !              \ patch the previous CALL  (*)
      ldn   e'|   250   NN,
      ldx   hl|   0     NN,
HERE  push  de|                \ <--- (†) main loop
      ldn   b'|   32    N,
HERE    push      bc|          \ <---+
        ld  a'|   (hl)|        \     |
        incx      hl|          \     |
        andn      248   N,     \     |
        outa      254   P,     \     |
        ld  a'|   e|           \     |
        cpl                    \     |
HERE      dec   a'|            \ <-+ |
          jrf  nz'| BACK,      \ --+ |
        pop bc|                \     |
      djnz  BACK,              \ ----+
      pop   de|
      ld    a'|   e|
      subn  24    N,
      cpn   30    N,
      retf   z|                \ return from routine
      retf  cy|                \ return from routine
      ld    a'|   e|
      cpl
HERE    ldn   b'| 40    N,     \ <--+
HERE      djnz    BACK,        \    |
        dec a'|                \    |
        jrf  nz'| BACK,        \ ---+
      jr    BACK,              \ ---> (†)
```

To test it you need to set CPU's speed at 3.5 MHz via **`SPEED!`**.

```
NEEDS SPEED!
0 SPEED! WHITE-NOISE
```

3.10.4 Assembler Example “ms” millisecond delay

This definition waits at least `u` milliseconds, with `u` < 8192, indentation helps to glimpse the various structures. The outer loop lasts exactly 3,500 T-states so that it can be used to produce milliseconds delays on a standard 3.5 MHz CPU. Some CPU time is spent to compute the correct number of iterations.
Also, this is an example of *forward relative-jump* **HOLDPLACE** resolved via **DISP,**

```
DECIMAL
CODE ms ( u -- )
    exx                                \ this to preserve BC and DE
    pop     hl|
    ld      a'|   l|
    ora      h|
    jrf     z'| HOLDPLACE              \ skip to end when u is zero (*)

        ldx     bc|   $243B NN,        \ get current CPU speed
        ldn     a'|      07 N,         \ to calculate the correct
        out(c)  a'|                    \ delay
        inc     b'|
        in(c)   a'|
        andn    3  N,
                                       \ this is a begin-while-repeat loop.
        HERE                           \ keep this address for later (♠)
        jrf     z'| HOLDPLACE          \ condidional forward to (♦)
            addhl   hl|                \ double HL based on CPU speed
            dec     a'|
            jr  SWAP BACK,             \ uncontidional loop back to (♠)
        HERE DISP,                     \ resolve forward jrf (♦)

        HERE                           \ begin of outer loop (♣)
            nop                        \    4 T
            ldn   b'| 204 N,           \    7 T
            HERE                       \        inner loop (♥)
                nop                    \ 3463 T = (4+13)*203 + (4+8)
            djnz  BACK,                \        back to inner loop (♥)
            decx  hl|                  \    6 T
            ld    a'|   l|             \    4 T
            ora    h|                  \    4 T
        jrf  nz'| BACK,                \   12 T   ( -5 T on final loop )
                                       \ 3500 T total
                                       \ repeat outer loop (♣)

    HERE DISP,                         \ resolve skip-to-end when zero (*)

    exx
    NEXT
C;
```

Some syntax-help definitions suitable for relative-jump instructions are:

HOLDPLACE --- a1

ALLOT the next byte as placeholder of a relative-jump displacement. The address a1 points to this placeholder and should be resolved by a subsequent **DISP,** or a derived definition.

DISP, a1 a2 ---

Compute the displacement from a2 to a1 and compile it to address a2 as displacement of a relative-jump op-code. The following snippet implements an IF-THEN phrase in Assembler:

```
cpn    HEX 60 N,
jrf  cy'|  HOLDPLACE                \ if lowercase
     subn  HEX 20  N,               \ quick'n'dirty uppercase
HERE DISP,                          \ aka THEN,
```

The following example implements a complete IF-THEN-ELSE phrase that check “carry-flag”:

```
jrf  cy'|  HOLDPLACE                \ IF,
     ldx   hl|    1   NN,
jr   HOLDPLACE  SWAP HERE DISP,     \ ELSE,
     ldx   hl|   -1   NN,
HERE DISP,                          \ THEN,
```

BACK, a1 ---

Compute the displacement from HERE to a1 and compile it to address HERE as displacement of a relative-jump op-code. The following example implements a BEGIN-UNTIL loop in Assembler:

```
\ Wait for a standard key-press.
HERE                                \ BEGIN,
    bit      5| (iy+ 1 )|           \ FLAGS (5C3A+1)
jrf     z'| BACK,                   \ UNTIL,
```

4 Technical specifications

4.1 Z80 CPU Registers

CPU Registers are used in the in the following way:

AF – Available for normal operations.
BC – *Forth Instruction Pointer:* should be preserved on Enter-and-Exit a definition and during ROM/OS calls.
DE – *Forth Return Stack Pointer*: should be preserved on Enter-and-Exit a definition and during ROM/OS calls.
HL – Available as *Work Register*

SP – *Forth Data Stack Pointer*

AF'– Available, sometime used for backup purpose
BC'– Available, used in I/O operations or tricky definitions
DE'– Available, often the Low part when used for 32-bit manipulations
HL'– Available, often the High part when used for 32-bit manipulations

IX – Used to point to the Forth "inner-interpreter": **i**t should be preserved during ROM/OS calls.
IY – Used by ZX System, must be preserved to let the standard keyboard to be served during Interrupts.

4.2 Single Cell 16 bits Integer Number Encoding

A 16 bits *integer* represents an integer number between –32768 and +32767 inclusive. The sign is kept in the most significant bit using the usual two-complement notation. Alternatively, the it represents an *unsigned integer* between 0 and +65535.

		H	L
16 bit:	HL:	**sbbb bbbb**	**bbbb bbbb**

In the CPU registers, an *integer* is kept in H and L where H is the most significant part.
In memory, an *integer* is stored in two contiguous bytes in the "little-endian" way, that is the lower address has the least significant part, in the L register. The byte at higher address has the most significant part, in the H register, as usual for the Zilog Z80 processor.

4.3 Two cells 32 bits Integer Number Encoding

The second integer format requires two *integers* to form a 32 bits number, referred to as *double* or *long*, that allows integers between –2,147,483,648 and +2,147,483,647 where the sign is kept on the most significant bit of the first *integer*.

Imagine a *double integer* stored in CPU register in this way:

	H'	L'	D'	E'
32 bits:	**sbbb bbbb**	**bbbb bbbb**	**bbbb bbbb**	**bbbb bbbb**

using register H', L', D' and E', with the most significant part in H', and the least in E'.

Then, on the Calculator Stack the double integer requires four contiguous bytes split into two integers with the most significant integer (HL') on top of Calculator Stack (i.e. in the lower addresses), and the least significant integer (DE') the second element from top, in the higher address, that is the second element from the top. So, it appears as L' H' E' D',

CPU	Calculator Stack
D'	SP + 3
E'	SP + 2
H'	SP + 1
L'	SP + 0 (Top Of Stack)

To adhere to the Standard, in RAM it is kept as L' H' E' D'. See how `2@` and `2!` are defined to understand this fact.

CPU	2VARIABLE
D'	Address + 3
E'	Address + 2
H'	Address + 1
L'	Address + 0

4.4 Double Cell Floating-Point Number Encoding

There is another optional format that use 32 bits as a *double integer*, but all bits are used in a different way to allows representation a *floating point number* approximately between ±0.3E-38 and ±1.7E+38 with 6-7 precision digits.
The sign is kept in the most significant bit, the same way as a *double integer*; then eight bits follow as the exponential part, then 23 bits of mantissa or significand. The sign in this position allows you reusing most of the semantics of *double integers* to deal with the sign.

```
                    H'          L'          D'          E'
32 bits f.p.:  | sxxx xxxx | xbbb bbbb | bbbb bbbb | bbbb bbbb |
```

See Floating-Point Option section for more details.

4.5 Single Cell 16 bits Heap Pointer Address Encoding

This is Spectrum Next's peculiar 16 bits *Heap Pointer* Address Encoding that leverages on MMU7 i.e. Z80 memory space addresses between $E000 and $FFFF. The three most significant bits represent an 8kibyte-page between 32 and 39 ($20 and $27), lower bits are taken as offset from $E000. A specific definition `>FAR` takes care of converting an heap-pointer address to an $E000 offset and paging to MMU7 the correct 8kibyte of physical RAM. Any NextZXOS call and most of I/O operations restore page 1 at MMU7 , so in most cases data stored in Heap has to be moved to PAD before being used elsewhere.

```
                                 H           L
16 bit:     HL:             | pppb bbbb | bbbb bbbb |

                 |    Page    |        Offset         |
                 | 0010 0ppp  | 111b bbbb | bbbb bbbb |
```

4.6 Dictionary memory structure

From version 1.7, a dictionary definition storage is splitted into two parts, the name-space in `HEAP` (see §**6.3)**, and the code-space in main memory. The name-space of a new definition begins at *heap-pointer address* (§**4.5**) given by **`HP`** (the current Heap Pointer), and the code-space part of it begins at **`HERE`** as usual, but all data previously contained in NFA, LFA and CFA are replaced by a single "backward" heap-pointer to point back to name-space location, as a "mirror".
The linked-list formed by each LFA uses *heap-pointers* to be decoded to actual RAM pointer via `>FAR`.

For example the two contiguos definitions **`SWAP`** and **`DUP`** appears in memory as follow (as per build 20231014, since it's perfectly possible that a different build shows different addresses):

```
Heap memory:
NFA     0302   | 84 | 53 57 41 D0 |        | len |   'S'  'W'  'A'  'P'  |
LFA     0307   | F8 02 |                   | 02F8 |  heap-pointer to previous NFA definition
CFA     0309   | 23 69 |                   | 6923 |  xt memory-address of this definition

Main memory:
Mirror  6921   | 09 03 |                   | 0309 |  backward-heap-pointer to  SWAP's  CFA
  xt    6923   |   E1   |      E3      |   E5    |  DD  E9  |
               | pop hl | ex (sp),hl | push hl |  jp (ix)  |

Heap memory:
NFA     030B   | 83 | 44 55 D0 |           | len |   'D'  'U'  'P'  |
LFA     030F   | 02 03 |                   | 0302 |  heap-pointer to previous NFA definition SWAP
CFA     0311   | 2A 69 |                   | 692A |  xt memory-address of this definition

Main memory:
Mirror  6928   | 11 03 |                   | 0311 |  backward-heap-pointer to  DUP's  CFA
  xt    692A   |   E1   |   E5    |   E5    | DD E9   |
               | pop hl | push hl | push hl |  jp (ix) |
```

You can verify yourself all of that by typing

```
SEE SWAP
Nfa: E302 84
Lfa: E307 2F8 TUCK
Cfa: 6921 E5E3
6921 E1 E3 E5 DD   E9 11 03 E1    ace]i  a

$E302 9 DUMP
E302 84 53 57 41   D0 F9 02 23     SWAPy #
E30A 69 83 44 55   D0 02 03 2A    I DUP  *
$6921 2 DUMP
691C 09 03 E1 E3   E5 DD E9 11     ace]i

SEE DUP
Nfa: E30B 83
Lfa: E30F 302 SWAP
Cfa: 692A E5E5
692A E1 E5 E5 DD   E9 18 03 D9    aee]i  Y

$E30B 8 DUMP
E30B 83 44 55 D0   01 03 2A 69     DUP  *i
$6923 2 DUMP
6928 11 03 E1 E5   E5 DD E9 19     aee]i
```

5 Error messages

Error messages strings are stored at Screens from # 4 to # 7 that are therefore reserved.

Code	Message	Meaning
------	--------------------------------	--
#0	is undefined.	Definition not found or number conversion invalid with this **BASE**
#1	Stack is empty.	Returning to “ok” prompt, the interpreter detects this situation
#2	Dictionary full.	
#3	No such a line.	Number shoulg be between 0 and 15
#4	has already been defined.	Creating a definition whose name already exists.
#5	Invalid stream.	
#6	No such a block.	Number should be between 1 and **#SEC**
#7	Stack full.	The interpreter detects more this situation
#8	Old dictionary is full.	
#9	Tape error.	
#10	Wrong array index.	
#11	Invalid floating point.	Issued during floating-double invalid operation
#12	Heap full.	
#13	Division by zero.	Issued during floating-double invalid operation
#14	Patching the wrong word.	
#17	Can't be executed.	
#18	Can't be compiled.	
#19	Syntax error.	
#20	Bad definition end.	
#21	is a protected word.	Trying to forget to an address below **FENCE**
#22	Aren't loading now.	
#23	Forget across vocabularies.	You have to use **DEFINITIONS** beforehand
#24	RS loading error.	
#25	Cannot open stream.	
#26	Error at postit time.	Issued by **ASSEMBLER** dictionary operation
#27	Inconsistent fixup.	Issued by **ASSEMBLER** dictionary operation
#28	Unexpected fixup/commaer.	Issued by **ASSEMBLER** dictionary operation
#29	Commaer data error.	Issued by **ASSEMBLER** dictionary operation
#30	Commaer wrong order.	Issued by **ASSEMBLER** dictionary operation
#31	Programming error.	Issued by **ASSEMBLER** dictionary operation
#33	Programming error.	Issued by **ASSEMBLER** dictionary operation
#34	Checksum error.	Issued by **ASSEMBLER** dictionary operation
#38	Not a BMP file.	
#39	NextZXOS Opendir error.	
#40	NextZXOS Out of memory.	
#41	NextZXOS Open error.	Issued to signal **F_OPEN** fails to open a file
#42	NextZXOS Close error.	Issued to signal **F_CLOSE** fails to close a file
#43	File not found.	Issued by **INCLUDE** or **NEEDS**
#44	NexZXOS doscall error.	Issued to signal a generic NextZXOS doscall error
#45	NextZXOS pos error.	Issued to signal **F_SEEK** fails to change current file position
#46	NextZXOS read error.	Issued to signal **F_READ** fails to read from file
#47	NextZXOS write error.	Issued to signal **F_WRITE** fails to write to file
#50	Incorrect result.	Used by **TESTING** suite
#51	Wrong number of result.	Used by **TESTING** suite
#52	Cell number before '->' does not match ...}T spec.	Used by **TESTING** suite
#53	Cell number before and after '->' does not match.	Used by **TESTING** suite
#54	Cell number after '->' below …}T does not match.	Used by **TESTING** suite

6 The Dictionary

6.1 The “core” dictionary

'*0x00*' --- (immediate)

This is a “ghost” definition executed by `INTERPRET` to go back to the caller once the text to be interpreted ends. This definition allows you to use a **0x00** (NUL ASCII) as the end-of-text indicator in the input text stream.

! n a ---

stores an integer `n` in the memory cell at address `a` and `a + 1`. Pronounced “store”.
Zilog Z80 microprocessor is a little-endian CPU that holds lower byte at lower address and higher byte in the higher address.

!CSP ---

saves the value of SP register in `CSP` user variable. It is used by **:** and **;** for syntax checking. ~~Also, CASE use it for the same purpose.~~

 # d1 --- d2

From a double number `d1` it produces the next ASCII character to be put in an output string using `HOLD`. The number `d2` is `d1` divided by the current `BASE` and is kept for subsequent elaborations. This definition is used between `<#` and `#>` . See also `#S`.

#> d --- a u

terminates a numeric conversion started by `<#` . This definition removes **d** and leaves the values suitable for `TYPE`.
See also `#` and `#S`.

#BUFF --- n

Constant, the number of available buffers. This build has 7 buffers located at address between `FIRST @` and `LIMIT @`.

#S d1 --- d2

This definition is equivalent of a series of `#` that is repeated until `d2` becomes zero. It is used between `<#` and `#>`.

#SEC --- n

This is a constant that gives the number maximum number of a `BLOCK`, so that half `#SEC` is the maximum number of a Screen. This system comes with a file “!Blocks-64.bin” that keeps persistency of all `BLOCK`s. Try `#SEC LIST`.

'   ---   cfa

Pronounced “tick”. Used in the form

```
' cccc
```

this definition leaves the **cfa** of definition `cccc`, that is its **xt** or the value to be compiled or passed to `EXECUTE`. If the definition `cccc` is not found after the `CURRENT` and `CONTEXT` search phases, then an error **#0** is raised, that is the message “`cccc` is undefined”. In a previous version of this Forth, this definition returned **pfa**: we changed this previous standard to return **cfa**.

(---   (immediate)

Enclose a comment. Used in the form

```
( cccc )
```

ignores what is between brackets. The space after `(` is not considered in `cccc`. The comment must be delimited in the same row with a closing `)` followed by a space or the end of line.

(+LOOP)   n   ---

This is the primitive low-level definition compiled by `+LOOP`.

(.")   ---

This is the primitive definition compiled by `."` and `.(`. It executes `TYPE`.

(;CODE)   ---

This is the primitive definition compiled by `;CODE`. It over-writes the **cfa** of `LATEST` definition to make it point to the machine code starting from the following address.

(?DO)   ---

This is the primitive definition compiled by `?DO`.
At compile-time it compiles the **cfa** of `(?DO)` followed by an offset as for `BRANCH` used to jump after the whole `?DO ... LOOP` structure in case the limit equals the initial index, otherwise it is equivalent to `(DO)`.

(?EMIT)   c1   ---   c2

Decodes the character `c1` using the following table. It is used internally by `EMIT`.

- $06 → print-comma
- $07 → bell rings
- $08 → back-space
- $09 → tabulator
- $0D → carriage return
- $0A → new line (emitted as a $0D on the fly)

For not listed character, `c2` is equal to `c1`.

(ABORT)   ---

Definition executed in case of error issued by `ERROR` when `WARNING` contains a negative number. This definition usually executes `ABORT` but can be patched with some user defined one at the PFA of `(ABORT)`.

(COMPARE)   a1 a2 n   --   b

This definition performs a lexicographic compare of `n` bytes of text at address `a1` with `n` bytes of text address `a2`. The compare is case-sensitive or case-insensitive based on the last execution of `CASEON` and `CASEOFF`.
When executed, this definition returns a numeric value
 0 : if strings are equal
+1 : if string at `a1` greater than string at `a2`
-1 : if string at `a1` less than string at a2
See also `CASEON` and `CASEOFF`.

(DO)   ---

This is the primitive compiled by `DO`.

(FIND)   a1 a2   --- cfa b tf
--- ff

Searches in the dictionary starting from address `a2` a definition which text name is kept at address `a1`; returns a `cfa`, the first byte `b` of nfa and a `tf` on a successful search; elsewhere a `ff` only.
The search is case-sensitive or case-insensitive based on the last execution of `CASEON` and `CASEOFF`.
Address `a2` must be the `nfa` of the first definition involved in the search in the vocabulary.
In previous versions of this Forth, it returned a `pfa`, we changed our mind, better a `cfa`.
Byte `b` keeps the length of the found definition in the least significant 5 bits, bit 6 is the `IMMEDIATE` flag. Bit 5 is the `SMUDGE` bit. Bit 7 is always set to mark the beginning or end of the `nfa`.
See also `CASEON` and `CASEOFF`.

(LEAVE)   ---

Direct procedure compiled by `LEAVE` that discards the current DO-LOOP frame and executes an unconditional jump. The memory cell following `(LEAVE)` contains the offset to be relatively added to the Instruction Pointer to jump after the corresponding `(LOOP)` or (+`LOOP)`.

(LINE)   n1 n2   --- a b

Retrieves Line `n1` of Screen `n2` and send it to buffer. It returns the address `a` within the buffer and a counter `b` that is `C/L` (=64) meaning a whole line.

(LOOP)   ---

This is the primitive compiled by `LOOP`. See also `DO` and `+LOOP`.

(MAP)   a2 a1 n c1 --- c2

Translate character `c1` using mapping string `a2` and `a2`. If `c1` is present within string `a1` then the corresponding position within string `a2` is taken as translation. If `c1` is not present within string `a1`, then it is not translated, and `c2` remanis equal to `c1`. `n` is the length of strings `a1` and `a2`.

For example, the following definitions are used to fix the illegal characters in a filename string:

```
create ndom hex    (   : ? / * | \ < > "   )
  char : c,  char ? c,  char / c,  char * c,
  char | c,  char \ c,  char < c,  char > c,  char " c,

create ncdm hex    (   % ^ % & $ _ { } ~   )
```

```
    char _ c,  char ^ c,  char % c,  char & c,
    char $ c,  char _ c,  char { c,  char } c,  char ~ c,

  : needs-ch ( a -- ) \ Replace illegal characters in filename string a
    count bounds
    Do
        ncdm ndom 9 i c@ (map) i c!
    Loop
  ;
```

(NEXT) --- **a**

Constant. It is the address of "next" entry point for the **Inner Interpreter**. When creating a new definition using machine code, the last op-code should be an unconditional jump to this address. If the newly created definition wants to return an *integer* value on TOS, it has to do it beforehand ~~it should jump to the previous address; and if it wants to return a *double integer* value, it should jump to the next previous one~~.

This Forth implementation *always* keeps `(NEXT)` value in **IX register.** For example, to create two definitions that disables and enables interrupts, without an `ASSEMBLER`, you could use the following snippet:

```
CODE   ISR-DI   HEX
  F3 C,          \  di
  DD C, E9 C,    \  jp (ix)
  SMUDGE         \  now a dictionary search will find this definition

CODE   ISR-EI   HEX
  FB C,          \  ei
  DD C, E9 C,    \  jp (ix)
  SMUDGE         \  now a dictionary search will find this definition
```

(NUMBER) **d a** --- **d2 a2**

Converts the ASCII text at address `a+1` in a double integer using the current `BASE`. Number `d2` is left on top of stack for any subsequent elaborations, `a2` is the address of the first non-converted character.
Used by `NUMBER` and `(EXP)` in the Floating-Point Option.

(PREFIX) **a** --- **a2**

During a `NUMBER` interpretation, if the character at address `a+1` is a "$" or a "%" modifies `BASE` accordingly and increments `a`: "$" for hexadecimal (base 16), "%" for binary (base 2).

(SGN) **a** --- **a2 f**

Determines if the character at address `a+1` is a sign (+ o −) and if found increments `a`. The flag `f` indicates the sign: `ff` for a positive sign `+` or no sign at all, `tf` for a negative sign − . If a is incremented then variable `DPL` is incremented as well. Used by da `NUMBER` and `(EXP)` in the Floating-Point Option.

***** **n1 n2** --- **n3**

Computes the product of two integers.

***/** **n1 n2 n3** --- **n4**

Compute (`n1` · `n2`) / `n3` using a double integer for the intermediate value to avoid precision loss.

***/MOD n1 n2 n3 --- n4 n5**

Leaves the quotient n5 and the reminder n4 of the operation (n1·n2) / n3 using a double integer for the intermediate to avoid precision loss.

+ n1 n2 --- n3

Leaves the sum of two integer.

+! n a ---

Adds to the cell at address a the number n. It is the same as the sequence a @ n + a !

+- n1 n2 --- n3

Computes n3 as n1 with the sign of n2. If n2 is zero, it means positive.

+BUF a1 --- a2 f

Advances the address of the buffer from a1 to a2, that is the next buffer. The flag f is false if a2 is the buffer pointed by PREV.

+LOOP n1 --- (run time)
a n2 --- (compile time)

Used in colon definition in the form

```
DO ... n1 +LOOP
```

At run-time +LOOP checks the return to the corresponding DO, n1 is added to the index and if the index did not cross the boundary between the loop limit minus one and the loop limit, the execution jumps back to the beginning of the loop. Otherwise the execution leaves the loop. On leaving the loop, the parameters are discarded and the execution continues with the following definition.
At compile-time +LOOP compiles (+LOOP) and a jump is calculated from HERE to a which is the address left on the stack by DO. The value n2 is used internally for syntax checking.

+ORIGIN n --- a

Returns the address n bytes after the “origin”. In this build the origin is 6400h. Used rarely to modify the boot-up parameters in the origin area.

+TO n --- cccc

Used in the form

```
n +TO cccc
```

If not compiling, add the value n to cccc . At compile-time it compiles a literal pointer to cccc's PFA followed by a plus-store-command (+!) so that later, at run-time the literal is used by the ! definition to alter cccc value.
Definition cccc was created via VALUE. See also TO. This definition is available after NEEDS +TO.

, **n** **---**

It puts `n` in the following cell of the dictionary and increments `DP` (dictionary pointer) of two locations.

," **---**

Compile a "Counted-ZString". It calls `WORD` to read characters from the current input stream up to a delimiter `"` and stores such a string at `HERE`. In a "Counted-ZString" the length of the string is stored as the first byte and the string itself ends with a NUL character (0x00). For example

```
,"  Hello"
```

compiles: **05 48 65 6C 6C 6F 00**

where 05 is the length of "Hello" string which is followed by a 00 'nul' character.

- **n1 n2** **---** **n3**

Computes `n3` = `n1` – `n2` as the difference from the penultimate and the last number on the stack.

--> **---**

Continues the interpretation in the next Screen during a `LOAD` .

-1 **---** **n**

This is the constant value -1 that in this implementation is 0FFFFh. Compiling a constant result in a faster execution than a literal.

-DUP **n** **---** **n n (non zero)**

n **---** **n (zero)**

Duplicates `n` if it is non zero. This definition is available only for backward compatibility. See also `?DUP`.

-FIND **---** **cfa b tf** **(ok)**

--- **ff** **(ko)**

Used in the form `-FIND cccc`.

It accepts a word (a non-space character sequence delimited by spaces) from the current input stream, storing it at address `HERE` + 1 and its length at `HERE`. Then, it run a search for it in the `CONTEXT` vocabulary first, then in the `CURRENT` vocabulary. If such a definition is found, it leaves the `cfa` of the definition, its length-byte `b` and a `tf`. Otherwise only a `ff`.

-TRAILING **a1 n1** **---** **a2 n2**

This definition assumes that a string `n1` characters long is already stored at address `a1` containing a space right-delimited word (a non-space character sequence delimited by spaces). It determines `n2` as the position of the first delimiter after the word.

. **n** **---**

Emits the integer `n` followed by a space.

." --- **(immediate)**

Used in the form

`." cccc"`

At compile-time, within a colon-definition, it accepts text from the input sources until a quote character (") is encountered, then it compiles the primitive to output the text followed by the string `cccc` . The text `cccc` is prepended by a length-counter that `TYPE` will use at run-time.

When interpreted, i.e. outside a colon-definition, immediately emits the text to output.

.(--- **(immediate)**

Used in the form

`.( cccc)`

acting as `." cccc "` but the string is delimited by a closed-parenthesis.

.C **c** --- **(immediate)**

Used in the form

`c .C xxxx C`

acting as `." xxxx"` but the string is delimited by character `c`. It is a more generic form of `.(` and `."` that, in fact, use this definition as their primitive.

.LINE **n1 n2** ---

Sends line `n1` of **BLOCK** `n2` to the current peripheral ignoring the trailing spaces.

.R **n1 n2** ---

Prints a number `n1` right aligned in a field `n2` character long, with no following spaces. If the number needs more than `n2` characters, the excess protrudes to the right.

/ **n1 n2** --- **n3**

Computes `n3` = `n1`/ `n2`, the quotient of the integer division. This system uses floored division via `M/MOD` and implements `UM/MOD` in machine-code, `FM/REM` and `SM/MOD` as derived definitions. See `M/MOD` for details.

/MOD **n1 n2** --- **n3 n4**

Computes the quotient `n4` and the reminder `n3` of the integer division `n1`/ `n2`. The reminder has the sign of `n1`. This system uses floored division via `M/MOD` and implements `UM/MOD` in machine-code, `FM/REM` and `SM/MOD` as derived definitions. See `M/MOD` for details.

0 --- **n**

This is a constant value zero. Compiling a constant results in a faster execution than a literal.

0< **n** --- **f**

Leaves a `tf` if `n` is less than zero, `ff` otherwise.

0= n --- f

Leaves a `tf` if `n` is not zero, `ff` otherwise. It is like a NOT `n`.

0> n --- f

Leaves a `tf` if `n` is greater than zero, `ff` otherwise.

0BRANCH f ---

Direct procedure that executes a conditional jump. If `f` is zero the offset in the cell following `0BRANCH` is added to the Instruction Pointer to jump forward of backward.
It is compiled by `IF`, `UNTIL` and `WHILE`.

1 --- n

Constant value 1. Compiling a constant results in a faster execution than a literal.

1+ n1 --- n2

Increments by one the number on TOS.

1- n1 --- n2

Decrements by one the number on TOS.

2 --- n

Constant value 2. Compiling a constant results in a faster execution than a literal.

2! d a ---
n-lo n-hi a ---

Stores the double integer held on TOS to address a.

2* n1 --- n2

Doubles the number on TOS.

2+ n1 --- n2

Increments by two the number on TOS.

2- n1 --- n2

Decrements by two the number on TOS.

2/ n1 --- n2

Halves the number on TOS.

```
2@              a           ---  d
                a           ---  n-lo  n-hi
```
Fetches the double integer at address a. to TOS.

```
2CONSTANT       d           ---  (immediate)        (compile time)
                            ---  d                  (run time)
```
This is a defining definition that creates a double constant. Used in the form

```
d 2CONSTANT cccc
```

it creates the new definition `cccc` which `pfa` holds the number **d**. When `cccc` is later executed it put **d** on TOS. This definition is not available at startup, it has to be loaded via `NEEDS 2CONSTANT`.

```
2DROP           d           ---
                n1  n2      ---
```
Discards a double integer from the TOS, i.e. discards the top two integer.

```
2DUP            d           ---  d   d
                n1  n2      ---  n1  n2  n1  n2
```
Duplicates the double integer on TOS, i.e. duplicates in order the two top integer.

```
2OVER           d1  d2      ---  d1  d2  d1
          n1  n2  n3  n4    ---  n1  n2  n3  n4  n1  n2
```
Copies to TOS the second double integer from top.
This definition isn't available at startup and must be included via `NEEDS 2OVER`.

```
2ROT      d1  d2  d3        ---  d2  d3  d1
     n1 n2 n3 n4 n5 n6      ---  n3  n4  n5  n6  n1  n2
```
Rotates the three top double integers, taking the third and putting it on top. The other two double integers are pushed down from top by one place. This definition isn't available at startup and must be included via `NEEDS 2ROT`.

```
2SWAP           d1  d2      ---  d2  d1
```
Swaps the two double integers on TOS.

```
2VARIABLE                   ---  (immediate)        (compile time)
                            ---  a                  (run time)
```
This is a defining definition used in the form:

```
2VARIABLE cccc
```

creates the new definition `cccc` with the pfa capable to hold a double-integer. When `cccc` is executed, it puts on TOS the pfa of `cccc` that is the address that holds the double-integere value.
When used in the form

```
cccc 2@
```

the content of the double-variable `cccc` is left on TOS.
When used in the form

d cccc 2!

the double-value on TOS is stored to the double-variable `cccc`.
This definition is not available at startup, it must be loaded via `NEEDS 2CONSTANT`.

3 --- n

Constant value 3. Compiling a constant results in a faster execution than a literal.

3DUP n1 n2 n3 --- n1 n2 n3 n1 n2 n3

Duplicates the three top integer on Stack. This definition is not available at startup, it must be loaded via `NEEDS 3DUP`.

: ---

This is a defining definition that creates and begins a colon-definition. Used in the form

: cccc ... ;

creates in the dictionary a new definition `cccc` so that, when later invoked, it executes the sequence of already existing definitions `'...'`. The `CONTEXT` vocabulary is set to be the `CURRENT` and compilation continues while the value of `STATE` is non-zero. Definitions having the bit 6 of its length-byte set are immediately executed instead of being compiled.

:NONAME --- xt

This is a defining definition that creates and begins a name-less colon-definition. It returns the `xt` of the word being defined. Such `xt` should be kept in some way, for example as a `CONSTANT`. Used in the form, for example

:NONAME ... ;
CONSTANT *cccc*

This definition is not available at startup, it must be loaded via `NEEDS :NONAME` but the source-file that contains this definition is named %noname.f

; --- (immediate)

Ends a colon-definition and stops compilation.. It compiles `EXIT` and executes `SMUDGE` to make the definition accessible to subsequent search.

;CODE --- (immediate)

Used in the form

: cccc ... ;CODE

terminates a colon definition stopping compilation of definition `cccc` and compiling `(;CODE)`.
Usually `;CODE` is followed by a suitable machine-code sequence. It is used to define a creator of new kinds of definitions.

;S ---

This definition is obsolete and kept for backward compatibility reasons only. It is usually the last xt compiled in a colon definition by ; and it does the action of returning to the calling definition. It is used to force the immediate end of a loading session started by LOAD.
Obsolete, prefer EXIT. This definition isn’t available at startup and must be included via NEEDS ;S sequence.

< **n1 n2 --- f**

Leaves a tf if n1 is less than n2, ff otherwise.

<# ---

Sets HLD to the value of PAD . It is used to format numbers using #, #S, SIGN and #>. The conversion is performed using a double integer, and the formatted text is kept in PAD.

<> **n1 n2 --- f**

Leaves a tf if n1 isn't equal to n2, ff otherwise. This definition isn't available at startup and must be included via NEEDS <> sequence and the file loaded is {}.f

<BUILDS ---

Used in a colon definition in the form

```
: cccc ... <BUILDS ... DOES> ... ;
```

Subsequent execution of cccc in the form

```
cccc nnnn
```

creates a new definition nnnn with an high-level procedure that at run-time calls the DOES> part of cccc . When nnnn is executed, the pfa of nnnn is put on TOS and the executed the following DOES>.
<BUILD and DOES> allow writing high-level procedures instead of using machine code as ;CODE would require.

The “Floating Point Option Library” available via NEEDS FLOATING provides a good example of use of this structure.

<BUILD differs from CREATE because it allocate the pointer to the DOES> part of the defining word.

<NAME **cfa --- nfa**

Converts a cfa in its nfa. It is the same as >BODY NFA sequence.
See also: CFA, LFA, NFA, PFA, >BODY.

= **n1 n2 --- f**

Leaves a tf if n1 equals to n2, ff otherwise.

> **n1 n2 --- f**

Leaves a tf if n1 is greater than n2, ff otherwise.

>BODY cfa --- pfa

Converts a cfa in its pfa.
See also: CFA, LFA, NFA, PFA, <NAME.

>IN --- a

User variable that keeps track of text position within an input buffer. WORD uses and modifies the value of >IN that is incremented when consuming input buffer.

>NUMBER d a u --- d2 a2 u2

This is the standard numeric conversion routine available for completeness only after NEEDS >NUMBER. This definition converts digits from the string a, u accumulating digits in number d. Conversion stops when any character that is not a legal digit is encountered returning the result d2 and the string parameters a2 and n2 for the remaining characters in the string. For historical reasons, this system doesn't use >NUMBER, instead it uses a non-standard version definition (NUMBER).

>R n ---

Takes an integer from TOS and puts it on top of the Return Stack. It should be used only within a colon-definition *and* the use of >R should be balanced with a corresponding R> within the same colon-definition.

? a ---

Prints the content of cell at address a. It is the same as the sequence: a @ .

?COMP ---

Raises an error message #17 if the current STATE is not compiling state.

?CSP ---

Raises an error message #20 if the value of CSP is different from the current value of SP register. It is used to check the compilation in a colon definition.

?DO n1 n2 --- (immediate) (run time)
--- a n (compile time)

Used in a colon definition in the form

```
?DO ... LOOP
?DO ... n3 +LOOP
```

It is used as DO to put in place a loop structure, but at run-time it first checks if n1 = n2 and in that case the loop is skipped. At run-time ?DO starts a sequence of definitions that will be repeated under control of an initial-index n2 and a limit n1. ?DO consumes these two value from stack and the corresponding LOOP increments the index. If the index did not cross the boundary between the loop limit minus one and the loop limit, then the executions returns to the corresponding ?DO, otherwise the two parameters are discarded and the execution continues after the LOOP.
The limit n1 and the initial value n2 are determined during the execution and can be the result of other previous operations. Inside a loop the definition I copies to TOS the current value of the index.
Se also: I, DO, LOOP, +LOOP, LEAVE. In particular LEAVE allows leaving the loop immediately.
At compile-time ?DO compiles (?DO) followed by an offset like BRANCH and leaves the address of the following location and the number n to syntax-check

?DO- [a1 n1] a n ---

This is a peculiar definition equivalent to `BACK` but fitted for `?DO`. It computes and compiles a relative offset from `a` to `HERE` and, in the case, it completes the `BRANCH` part previously compiled by `?DO` that left `a1` and `n1`. It is used by `LOOP`, `+LOOP`. If the loop begins with `DO` then `a1` and `n1` won't be there and no `BRANCH` will be compiled.

?DUP n --- n n (non zero)
n --- n (zero)

Duplicates the value on TOS if it is not qual to zero. This is the same as `-DUP`.

?ERROR f n ---

Raises an error message #`n` if `f` is true.

?EXEC ---

Raises an error message #18 if we aren't compiling.

?LOADING ---

Raises an error message #22 if we aren't loading. It show the illegal use of `-->` .

?PAIRS n1 n2 ---

Raises an error message #19 if n1 is different from n2. It is used for syntax checking by the definitions that completes the construction of structures `DO`, `BEGIN`, `IF`, `CASE`.

?STACK ---

Raises an error message #1 if the stack is empty and we tried to consume an element from the calculator stack. On the other hand, an error message #7 if the stack is full.

?TERMINAL --- f

Tests the keyboard for a [BREAK] key-press. Leaves a `tf` if the [BREAK] key is pressed, `ff` otherwise. Useful to stop an indefinite loop, for example:

```
BEGIN ... ?TERMINAL UNTIL
```

@ a --- n

Reads cell at address `a` and put an integer on TOS.

ABORT ---

Clears the stack and pass to prompt command, ~~prints the copyright message~~ and returns the control to the human operator executing `QUIT`.

ABORT" f ---

Used in a colon definition in the form

```
test ABORT" cccc" ...
```

At run-time if TOS is non-zero, prints the message `cccc` and executes `-1 ERROR` and then `ABORT` to return to command-prompt. If TOS is zero does nothing and passes to the instruction after the message.

ABS **n** **---** **u**

Leaves the absolute value of `n`.

ACCEPT **a n1** **---** **n2**

Transfers characters from the input terminal to the address `a` for `n1` location or until receiving a 0x13 “CR” character. A 0x00 “null” character is added. It leaves on TOS `n2` as the actual length of the received string. More, `n2` is also copied in `SPAN` user variable. See also `QUERY`.

AGAIN **---** **(immediate)** **(run time)**

a n **---** **(compile time)**

Used in colon definition in the form

```
BEGIN ... AGAIN
```

At run-time `AGAIN` forces the jump to the corresponding `BEGIN` and has no effect on the calculator stack. The execution cannot leave the loop (at least until a `R>` is executed at a lower level).
At compile-time `AGAIN` compiles `BRANCH` with an offset from `HERE` to `a`. The number `n` is used for syntax-check.

ALLOT **n** **---**

This definition is used to reserve some space in the dictionary or to free memory. It adds the signed integer `n` to `DP` (Dictionary Pointer) user variable.

ALIGN **---**

force `HERE` to an even address. This definition is available after `NEEDS ALIGN`.

ALIGNED **a1** **---** **a2**

force `a1` to an even address. This definition is available after `NEEDS ALIGNED`.

AND **n1 n2** **---** **n3**

It executes an bitwise AND operation between the two integers. The operation is performed bit by bit.

AUTOEXEC **---**

This definition is executed the first time the Forth system boots and **loads Screen# 11**. Once called, it patches `ABORT` definition to prevent any further executions at startup. Anyway, you can still invoke it directly.
This allows you to perform some automatic action at startup.

B/BUF **---** **n**

Constant. Number of bytes per buffer. In this implementation is 512.

B/SCR --- **n**

Constant that indicates the number of Blocks per Screen. In Next version is 2, that means a Screen is 1024 byte long. In Microdrive version it was 1…

BACK **a** ---

Computes and compiles a relative offset from a to `HERE`. Used by `AGAIN`, `UNTIL`, `LOOP`, `+LOOP`.

BASE --- **a**

User variable that indicates the current numbering base used in input/output conversions. It is changed by `DECIMAL` that put ten, HEX that put sixteen, and with some extensions `BINARY` that put two and `OCTAL` that put eight.

BASIC **u** ---

Quits Forth and returns to Basic returning to the caller USR the unsigned integer on TOS.

BEGIN --- **(immediate)** **(run time)**

--- **a n** **(compile time)**

Used in colon definition in one of the following forms

```
BEGIN ...   AGAIN              or
BEGIN ... f UNTIL              or
BEGIN ... f WHILE ... REPEAT   or
BEGIN ... f END
```

At compile-time, it starts one of these structures.
At run-time `BEGIN` marks the beginning of a definitions sequence to be repeatedly executed and indicates the jump point for the corresponding `AGAIN`, `REPEAT`, `UNTIL` or `END`.
With `UNTIL`, the jump to the corresponding BEGIN happens if on TOS there is a `ff`, otherwise it quits the loop.
With `AGAIN` and `REPEAT`, the jump to the corresponding BEGIN always happens.
The `WHILE` part is executed if and only if on TOS there is a `tf`, otherwise it quits the loop.

BINARY ---

Sets `BASE` to 2, that is the binary base. This definition is available after `NEEDS BINARY`.

BL --- **c**

Constant for "Blank". This implementation uses ASCII and `BL` is 32.

BLANK **a n** ---

Fills with "Blank" `n` location starting from address `a`.

BLK --- **a**

User variable that indicates the current `BLOCK` to be interpreted. If zero then the input is taken from the terminal buffer `TIB`.

BLK-FH --- a

Variable containing file-handle to block's file !Blocks-64.bin.

BLK-FNAME --- a

Variable containing the counted-zstring `"!Block-64.bin"` . as produced by `,"` definition.
See also `,"` definition.

BLK-INIT ---

Initialize BLOCK system. It opens for update (read/write) file `"!Block-64.bin"` .

BLK-READ a n ---

Read block n to address a. `See also F_READ.`

BLK-SEEK n ---

Seek block n within blocks!.bin file. `See also F_SEEK.`

BLK-WRITE a n ---

Take text content at address a to disk block `n`. `See also F_WRITE.`

BLOCK n --- a

Leaves the address of the buffer that contains the block `n`. If the block isn't already there, it is fetched from disk. If in the buffer there was another buffer and it was modified, then it is re-written to disk before reading the block n.
See also `BUFFER`, `R/W`, `UPDATE`, `FLUSH`.

BOUNDS a n --- a+n a

Given an address and a length (a n) calculate the bound addresses suitable for `DO ... LOOP`.
It is used by `TYPE`.

BRANCH ---

Direct procedure that executes an unconditional jump. The memory cell following `BRANCH` has the offset to be relatively added to the Instruction Pointer to jump forward or backward. It is compiled by `AGAIN`, `ELSE`, `REPEAT`.

BUFFER n --- a

Makes the next buffer available assigning it the block number `n`. If the buffer was marked as modified (by `UPDATE`), such buffer is re-written to disk. The block is not read from disk. The address point to the first character of the buffer.

BYE ---

Executes `FLUSH` and `EMPTY-BUFFERS`, then quits Forth and returns to Basic returning to the caller USR the value of `0 +ORIGIN`. See also `BASIC`.

C! b a ---

Stores a byte `b` to address `a`.

C, b ---

Puts a byte `b` in the next location available in the dictionary and increments `DP` (dictionary pointer) by 1.

C/L --- c

Constant that indicate the number of characters per screen line. In this implementation it is 32.

C@ a --- b

Puts on TOS the byte at address `a`.

CALL# n1 a --- n2

Performs a CALL to the routine at address `a`. First argument `n1` is passed via bc register *and* a register. The routine can return bc register which is pushed on TOS. This definition is useful to call normal ZX Spectrum ROM routines.
This definition is available after `NEEDS CALL#`.

CASEOFF ---

Sets case-sensitive search OFF. changes the system behavior so that `(FIND)` can search the dictionary ignoring case, and `(COMPARE)` compares two strings ignoring case.

CASEON ---

Sets case-sensitive search ON. It changes the system behavior so that (FIND) will search the dictionary case sensitive, and (COMPARE) will compare the two strings case sensitive.

CELL --- 2

In this implementation a cell is two bytes. This definition is available after `NEEDS CELL`.

CELL+ n1 --- n2

Increments `n1` by 1 "cell", that is two units. In this implementation a cell is two bytes.

CELL- n1 --- n2

Decrements `n1` by 1 "cell", that is two units. In this implementation a cell is two bytes.

CELLS n1 --- n2

Doubles the number `n1` on TOS giving the number of bytes equialent to `n1` "cells". In this implementation a cell is two bytes.

CFA pfa --- cfa

Converts a `pfa` in its `cfa`. See also `LFA`, `NFA`, `PFA`, `>BODY`, `<NAME`.

CHAR --- c

Used in the form

CHAR c

determines the first character of the next definition in the input stream.

CLS ---

Clears the screen using the ZX Spectrum ROM routine 0DAFh.

CMOVE a1 a2 n ---

Copies the content of memory starting at address a1 for n bytes, storing them from address a2. The content of address a1 is moved first. See also CMOVE>.

CMOVE> a1 a2 n ---

The same as CMOVE but the copy process starts from location a1 + n - 1 proceding backward to the location a1.

CODE ---

Defining definition used in the form

CODE cccc

it creates a new dictionary entry for the definition cccc with the cfa ~~of such a definition pointing to its pfa~~ that is empty for the moment, HERE points that location; then some machine-code instruction should be added using C, that will be compiled from HERE onwards. The new definition is created in the CURRENT vocabulary but won't be found by (FIND) because it has the SMUDGE bit set. Once the definition construction is complete, it is programmer's responsibility to execute SMUDGE to make visible.

This definition is redefined / overridden by ASSEMBLER vocabulary available after LOADing Screens 100-165, this allows the programmer to use a pseudo-standard Z80 notation to create a new low-level definition using assembler directly.

Here is an example that creates a definition SYNC-FRAME to wait for the next maskable interrupt:

```
CODE SYNC-FRAME HEX
     76 C,        \ halt       ;  wait for interrupt or reset
     DD C, E9 C, \ jp (ix)    ;  jump to the inner interpreter
     SMUDGE
```

COLD ---

This definition executes the Cold Start procedure that restore the system at its startup state.
It sets DP to the minimum standard and executes ABORT.

COMPILE ---

Used in the form

COMPILE cccc

At compile-time, it determines the xt of the definition that follows COMPILE and compile it in the next dictionary cell.

COMPILE, xt ---

Used within a colon-definition, it puts xt in the following cell of the dictionary and increments DP (dictionary pointer) of two locations.

```
CONSTANT        n           ---   (immediate)          (compile time)
                            ---   n                    (run time)
```

Defining definition that creates a constant. Used in the form

```
n CONSTANT cccc
```

it creates the definition `cccc` and `pfa` holds the number n. When `cccc` is later executed it put n on TOS.

```
CONTEXT                     ---   a
```

User variable that points to the vocabulary address where a definition search begins.

```
COUNT           a1          ---   a2  b
```

Leaves the address of text `a2` and a length `b`. It expects that the byte at address `a1` to be the length-counter and the text begins to the next location.

```
CR                          ---
```

Transmits a 0x0D to the current output peripheral.

```
CREATE                      ---                        (compile time)
                            ---   a                    (run time)
```

Defining definition used in the form

```
CREATE cccc
```

it creates a new dictionary entry for the definition `cccc` with the **pfa** still empty.
When `cccc` is executed, it puts on TOS the **pfa** of `cccc`
Often used with `ALLOT` to reserve space in the dictionary to be later used, for instance as an array.
See also `VARIABLE`.

```
CSP                         ---   a
```

User variable that temporarily holds the value of SP register during a compilation syntax error check.

```
CURRENT                     ---   a
```

User variable that points to the address in the Forth vocabulary where a search continues after a failing search executed in the `CONTEXT` vocabulary. See also `LATEST`.

```
CURS                        ---
```

Shows a (flashing) cursor on current video position and wait for a keypress.
Depending on CAPS-LOCK state, the faces of flashing cursor are different depending on the content of a few bytes in ORIGIN area:

```
HEX
026 +ORIGIN C@ . → 8F      █      Full square graphic character
027 +ORIGIN C@ . → 8C      ▄      Lower-half square graphic character
028 +ORIGIN C@ . → 5F      _      Underscore character
```

When CAPS-LOCK is On the cursor switches between █ (8F) and _ (5F)

When CAPS-LOCK is Off the cursor switches between █ (8F) and ▄ (8C)
You can modify this behavior putting some suitable values on these three bytes. For example you can make disappear the flashing cursor using the following patch:

```
HEX
BL 026 +ORIGIN C!
BL 027 +ORIGIN C!
BL 028 +ORIGIN C!
```

D+ d1 d2 --- d3

Computes `d3` as the sum of `d1` and `d2`. This is a 32 bits sum.

D+- d1 n --- d2

Forces the double integer `d1` to have the the sign of `n`.
It is used by `DABS` .

D- d1 d2 --- d3

Subtract d2 from d1. This is a 32 bits subtraction. Available after `NEEDS D-`.

D. d ---
n-lo n-hi ---

Emits a double integer followed by a space. The double integer is kept on stack in the format `n-lo n-hi` and the integer on TOS is the most significant.

D.R d n ---

Emits a double integer rigth aligned in a field `n` character wide. No space follows. If the field is not large enough, then the excess protrudes to the right.

D0= d --- f

True if `d1` = 0. This is a 32 bits comaprison. Available after `NEEDS D0=`.

D< d1 d2 --- f

True if `d1` < `d2`. This is a 32 bits comaprison. Available after `NEEDS D<`.

D= d1 d2 --- f

True if `d1` equals `d2`. This is a 32 bits comaprison. Available after `NEEDS D=`.

DABS d --- ud

Leaves the absolute value of a double integer.

DECIMAL ---

Sets `BASE` to 10, that is the decimal base.

DEFINITIONS ---

To be used in the form

cccc DEFINITIONS

it sets the CURRENT vocabulary to be the CONTEXT vocabulary and this allows adding new definitions to cccc vocabulary.
For example: FORTH DEFINITIONS or ASSEMBLER DEFINITIONS.
In this implementation a Forth oriented ASSEMBLER vocabulary is available as an extra-option that can be LOADed from Screens 100 -160.

DEVICE --- a

Variable that holds the number of current channel: 2 for video, 3 for printer, and any number between 4 and 15 to refer to a Basic OPEN# channel.

DIGIT c n --- u tf (ok)
c n --- ff (ko)

Converts the ASCII character c in the equivalent number using the base n, followed by a a tf. If the conversion fails it leaves a ff only.

DLITERAL d --- d (immediate) (run time)
d --- (compile time)

Same as LITERAL but a 32 bits number is compiled. DLITERAL is an immediate definition that is executed and not compiled.

DMAX d1 d2 --- d3

Leaves the maximum between d1 and d2. Available after NEEDS DMAX.

DMIN d1 d2 --- d3

Leaves the minimum between d1 and d2. Available after NEEDS DMIN.

DNEGATE d1 --- d2

Computes the opposite double number.

DO n1 n2 --- (immediate) (run time)
--- a n (compile time)

Used in colon definition in the form

DO ... LOOP or
DO ... n +LOOP

It is used to put in place a loop structure: The execution of DO starts a sequence of definitions that will be repeated, under control of an initial-index n2 and a limit n1. DO drops these two value from stack and the corresponding LOOP increments the index. If the index did not cross the boundary between the loop limit minus one and the loop limit, then the executions returns to the corresponding DO, otherwise the two parameters are discarded and the execution continues after the LOOP.
The limit n1 and the initial value n2 are determined during the execution and can be the result of other previous

operations. Inside a loop the definition `I` copies to TOS the current value of the index.
See also: `I`, DO, `LOOP`, `+LOOP`, `LEAVE`. In particular LEAVE allows leaving the loop immediately.
At compile-time `DO` compiles `(DO)` and leaves the address of the following location and the number `n` to syntax-check.

DOES> ---

Definition that defines the execution action of a high-level creative definition. `DOES>` changes the **pfa** of the definition being defined to point the definitions sequence compiled after `DOES>`. It is used in conjunction with `<BUILDS`. When the machine-code part of `DOES>` is executed, it leaves on TOS the **pfa** of the new definition, and this allows the interpreter to use this area. Obvious uses are new vocabularies (Assembler), multidimensional array, closures, and other compiling operations.

The “Floating Point Option Library” available via `NEEDS FLOATING` provides a good example of use of this structure.

DP --- **a**

User variable (Dictionary Pointer) that holds the address of next available memory location in the dictionary. It is read by `HERE` and modified by `ALLOT`.

DPL --- **a**

User variable that holds the number of digits after the decimal point during the interpretation of double integer. It can be used to keep track of the column of the decimal point during a number format output. For 16 bit integer it defaults to –1. It takes into account the exponential part and its sign for floating point numbers.

DROP **n** ---

Drops the value on TOS. See also `OVER`, `NIP`, `TUCK`, `SWAP`, `DUP`, `ROT`.

DUP **n** --- **n n**

Duplicates the value on TOS. See also `OVER`, `DROP`, `NIP`, `TUCK`, `SWAP`, `ROT`.

DUP>R **n** --- **n**

Copy TOS to the Return Stack. See also `DUP`, `>R`, `R@`.

DU< **ud1 ud2** --- **f**

True if `ud1` < `ud2`. This is a 32 bits comaprison. Available after `NEEDS D<`.

ELSE **a1 n1** --- **a2 n2** **(immediate)** **(compile time)**
--- **(run time)**

Used in colon definition in the form

```
IF ... ELSE ... ENDIF
IF ... ELSE ... THEN
```

At run-time `ELSE` forces the execution of the false part of an IF-ELSE-ENDIF structure. It has no effects on the stack.
At compile-time `ELSE` compiles `BRANCH` and prepares the following cell for the relative offset, stores at `a1` the previous offset from `HERE`; then it leaves `a2` and `n2` for syntax checking.

EMIT **c** **---**

Sends a printable ASCII character to the current output peripheal. `OUT` is incremented. `7 EMIT` activates an acoustic signal. The 'null' 0x00 ASCII character is not transmitted.

EMITC **b** **---**

Sends a byte b character to the current output peripheal selected with `SELECT`. See also `DEVICE`.

EMPTY-BUFFERS **---**

Erases all buffers. Any data stored to buffers after the previous `FLUSH` is lost.

ENCLOSE **a c** **--- a n1 n2 n3**

Starting from address `a`, and using a delimiter character `c`, it determines the offset `n1` of the first non-delimiter character, `n2` of the first delimiter after the text, `n3` of first character non enclosed.
This definition doesn't go beyond a 'null' ASCII that represent a unconditional delimiter. For example:

```
1:   c  c  x  x  x  c  x       →    2  5  6
2:   c  c  x  x  x  'null'     →    2  5  5
3:   c  c  'null'              →    2  3  2
```

END **a n** **--- (immediate)** **(compile time)**
f **---** **(run time)**

Synonym of `UNTIL`.

ENDIF **a n** **--- (immediate)** **(compile time)**

At run-time, `ENDIF` indicates the destination of the forward jump from `IF` or `ELSE`. It marks the end of a conditional structure. `THEN` is a synonym of `ENDIF`.
At compile-time `ENDIF` calculates the forward jump offset from `a` to `HERE` and store it at a. The number `n` is used for syntax checking.

ERASE **a n ---**

Erases `n` memory location starting from `a`, filling them with 'null' characters (0x00).

ERROR **b** **--- n1 n2**
--- ff

Notifies an error b and resets the system to command prompt. First of all, the user variable `WARNING` is examined.
If `WARNING` is 0 then the offending definition is printed followed by a "?" character and a short message "MSG#n".
If `WARNING` is 1, instead of the short message, the text available on line b of `BLOCK` 4 is displayed. Such a number can be positive ~~or negative~~ and lay beyond block 4.
If `WARNING` is –1 then `ABORT` is executed, which resets the system to command prompt. The user can (with care) modify this behavior of that by altering `(ABORT)`.
If `BLK` is non zero, then `ERROR` leaves on the stack `n1` that is the value of `IN` and `n2` that is the value of `BLK` at the error moment. These numbers can then be used by `WHERE` to determine and show the exact error position.
If `BLK` is zero, then only a `ff` is left on TOS.
In all cases, the final action is `QUIT`.

EXEC: **n** **---**

Vectorised fast case structure. Used in colon-definition in the form

```
: MY_ACTION_LIST ( n -- )
  EXEC:
      word0   \ executed when n = 0
      word1   \ executed when n = 1
      word2   \ executed when n = 2
    ...
;
```

to execute the definition indexed by `n` .

Warning: there is no run-time checking on `n` and if `n` is out of range, then a crash is likely to happen.

This definition is not available at startup, it must be loaded via `NEEDS EXEC:` . The source file is EXEC_.f

EXECUTE **cfa** **---**

Executes the definition which `cfa` is held on TOS.

EXIT **---**

This is (usually) the last definition compiled in a colon definition by `;` doing the action of returning to the calling definition. It is used to force the immediate end of a loading session started by `LOAD`.

EXP **--- a**

User variable that holds the exponent in a floating-point conversion. It is not used until the *Floating Point Option* is enabled via `NEEDS FLOATING`.

EXPECT **a n ---**

Transfers characters from the input terminal to the address `a` for `n` location or until receiving a 0x13 “CR” character. A 0x00 “null” character is added in the following location. The actual length of the received string is kept in `SPAN` user variable. See also `ACCEPT`. This definition isn't available at startup, it must be loaded using `NEEDS EXPECT`.

FENCE **--- a**

User variable that holds the (minimum) address to where `FORGET` can act.

FILL **a n b ---**

Fills `n` memory location starting from address `a` with the value of `b`.

FIRST **--- a**

User variable that holds the address of the first buffer. See also `LIMIT`.

FLD --- a

User variable that holds the width of output field.

FLIP n1 --- n2

Exchange high and lower byte of n1. Available after `NEEDS FLIP`.

FLUSH ---

Executes `SAVE-BUFFERS`. It saves to disk the buffers marked “modified” by `UPDATE`.

FM/MOD d n1 --- n2 n3

Floored Division. Leaves the quotient `n3` and the reminder `n2` of the integer division of `d` /`n1`.
This system has only UM/MOD coded in machine-code.

Dividend	Divisor	Remainder	Quotient
10	7	3	1
-10	7	4	-2
10	-7	-4	-2
-10	-7	-3	1

FORGET ---

Used in the form

```
FORGET cccc
```

removes from the dictionary the definition `cccc` and all the preceding definitions. Care must be put when more than one `VOCABULARY` is involved. Use `MARKER` instead.
See also `DP`.

FORTH --- (immediate)

This is the name of the first vocabulary. Executing `FORTH` sets this to be the CONTEXT vocabulary. As soon as no new vocabulary is defined, all new colon definitions became part of `FORTH` vocabulary. `FORTH` is immediate, so it is executed during the creation of a colon definition to select the needed vocabulary. See also `ASSEMBLER` (optional vocabulary).

F_CLOSE n --- f

NextZXOS primitive: it closes a file handle `n` previously opened with `F_OPEN`. Flag `f` is 0 for OK. It uses an RST 8 call followed by $9B service number.

F_FGETPOS n --- d f

NextZXOS primitive: given an open file handle `n` returns the position `d`. Flag `f` is 0 for OK.

F_GETLINE a n1 fh --- n2

Given a filehandle read at most `n1` characters as the next line (terminated with $0D or $0A) and stores it at address `a` and returns `n2` as the number of bytes read, i.e. the length of line just read.

F_INCLUDE n ---

Given an open file-handle `n`, this definition includes the source from file. This definition is used by `INCLUDE` and `NEEDS`.

F_OPEN a1 a2 n1 --- n2 f

NextZXOS primitive: it opens a file using filespec given at address `a1` and returns filehandle number `n`, `n1` is “mode” as specified in “NextZXOS and esxDOS APIs” standard documentation. Filespec is a NUL-termianted string. Flag `f` is 0 for OK. It uses an RST 8 call followed by $9A service number. See `F_CLOSE`.

F_READ a n1 n2 --- n3 f

NextZXOS primitive: it reads at most `n1` bytes from file handle `n2` and stores them at address a. Returns `n3` as the actual bytes read. Flag `f` is 0 for OK. It uses RST 8 call followed by $9D service number.

F_SEEK d n ---

NextZXOS primitive: it seeks position `d` at open file given by filehandle `n`. It uses an RST 8 call followed by $9F service number. Flag `f` is 0 for OK.

F_SYNC n --- f

NextZXOS primitive: it syncs to disk open file given by filehandle `n`. It uses an RST 8 call followed by $9C service number. Flag `f` is 0 for OK.

F_WRITE a n1 n2 --- n3 f

NextZXOS primitive: it takes `n1` bytes at address a and writes them to filehandle `n2`. It uses an RST 8 call followed by $9F service number. Returns `n3` as the actual bytes written. Flag `f` is 0 for OK.

HANDLER --- a

User variable that holds the current error-handler. See `CATCH` and `THROW`.

HERE --- a

Leaves the address of next location available on the dictionary.

HEX ---

Changes the base to hexadecimal, setting `BASE` to 16.

HLD --- a

User variable that holds the address of last character used in a numeric conversion output.

HOLD c ---

Used between `<#` and `#>` to put a ASCII character during a numeric format.

HP --- a

User variable that holds the heap-address of the first free byte on Heap. See `HEAP` section.

HP, n ---

Puts `n` in the next location available in the heap and increments `HP` (heap pointer) by 2.

I --- n

Used between `DO` and `LOOP` (or `DO` and `+LOOP`, `?DO` and `LOOP`, `?DO` and `+LOOP`) to put on TOS the current value of the loop index.

I' --- n

Used between `DO` and `LOOP` (or `DO` and `+LOOP`, `?DO` and `LOOP`, `?DO` and `+LOOP`). It puts on TOS the *limit* of the loop. This definition isn't available at startup and must be included via `NEEDS I'`.

ID. nfa ---

It prints the definition name whose `nfa` is on TOS.

IF f --- (immediate) (run time)
--- a n (compile time)

Used in colon definition in the form

```
IF ... ENDIF
IF ... ELSE ... ENDIF
```

At run-time `IF` selects which definitions sequence to execute based on the flag on TOS:
If f is true, the execution continues with the instruction that follows IF ("true" part).
If f is false, the execution continues after the `ELSE` ("false" part).
At the end of the two parts, the executions always continues after `ENDIF`.
`ELSE` and its "false" part are optional and if omitted no "false part" will be executed and execution continues after ENDIF.
At compile time IF compiles `0BRANCH` reserving a cell for an offset to the point after the corresponding ELSE or ENDIF .
The integer `n` is used for syntax checking.

IMMEDIATE ---

Marks the latest definition such that at compile-time it is always executed instead of being compiled. The bit 6 of the length byte of the definition is set. This allows such a definition to handle complex compilation situation instead of burdening the main compiler.
The user can force the compilation of an immediate definition prepending a `[COMPILE]` to it.

INCLUDE ---

It is used in in the form:

```
INCLUDE cccc
```

starts interpretation of text read from file cccc.
This definition has a known bug, the `INCLUDE`d source text file must end with an empty line.
See also `NEEDS` and `LOAD`

INDEX **n1 n2 ---**

Prints the first line of all screens between `n1` and `n2`. Useful to quick check the content of a series of screens.

INKEY **--- b**

Reads the next character available from current stream and previously selected with `SELECT` leving it on TOS. It is the opposite of `EMITC`.

INTERPRET **---**

This is the text interpreter. It executes or compiles, depending on the value of `STATE`, text from input buffer a word at a time. It first searches on `CONTEXT` and `CURRENT` vocabularies; if they fail, the text is interpreted as a numeric value, converted using the current `BASE`, and put on TOS. If that numeric conversion fails too, an error is notified with the symbol "?" followed by the word that caused the error. `INTERPRET` executes `NUMBER` and the presence of a decimal point "." indicates that the number is assumed as double integer instead of a simple integer.
After execution of the found definition, the control is given back to the caller procedure.

INVERT **n1 --- n2**

Inverts all bits. This definition is available after `NEEDS INVERT`.

INVV **---**

"Inverse video". It enables Inverse-Video attribute mode. See also `TRUV`.
This definition isn't available at startup and must be included via `NEEDS INVV`.

J **--- n**

Used inside a DO-LOOP gives the index of the *first* outer loop. See also `I`.
This definition isn't available at startup and must be included via `NEEDS J`.
E.g.

```
DO .. DO .. J .. LOOP .. LOOP
```

In this case **J** is used to get the index of the outer DO-LOOP while **I** gives the index of the inner DO-LOOP.

K **--- n**

Used inside a DO-LOOP gives the index of the *second* outer loop. See also **I**.
This definition isn't available at startup and must be included via `NEEDS K`.
E.g.

```
DO .. DO .. DO .. K .. LOOP .. LOOP .. LOOP
```

Anyway, in Forth, it isn't a good programming technique nesting loop, better split the definition.

KEY **--- b**

Waits for a key-press, without showing a flashing cursor. It leaves the ASCII code b of the character read from keyboard without printing it to video. In this implementation some SYMBOL-SHIFT key combinations are decoded as follow:

E2	STOP	→	7E	~
C3	NOT	→	7C	|
CD	STEP	→	5C	\
CC	TO	→	7B	{
CB	THEN	→	7D	}
C6	AND	→	5B	[
C5	OR	→	5D	]
AC	AT	→	7F	©
C7	<=	→	20	same as SHIFT-1 [EDIT]

C9 <> → 06 same as CAPS-SHIFT + 2 and toggles CAPS-LOCK On and Off
C8 >= → 20 same as SHIFT-0 [BACKSPACE]

L/SCR --- n

Constant that indicates the number of lines per Screen. In this implementation is 16.

LATEST --- nfa

Leaves the `nfa` of the latest definition in CURRENT vocabulary.

LEAVE ---

Forces the conclusion of a `DO ... LOOP` by compiling `(LEAVE)` followed by an offset to the first instruction after the corresponding `LOOP` or `+LOOP`.

LFA pfa --- lfa

Converts a pfa in its lfa. See also `CFA`, `NFA`, `PFA`, `>BODY`, `<NAME`.

LIMIT --- a

User variable that points to the first location above the last buffer. Normally it is the top of RAM, but not always. In this implementation, it set at $E000 to allow MMU7 as a general purpose 8K RAM bank. See also: `FIRST`.

LIST n ---

Prints screen number n and sets `SCR` to `n`.

LIT --- n

Puts on TOS the value hold in the following location. It is automatically compiled a before each literal number.

LITERAL n --- n (immediate) (run time)
n --- (compile time)

Compile-time, `LITERAL` compiles `LIT` followed by the value `n` in the following cell. This is an immediate definition and, even within a colon definition, it will be executed.
It is used in the form

```
: cccc ... [ calculations ] LITERAL ... ;
```

the compilation is suspended during the calculations and, when compilation resumes, `LITERAL` compiles the value put on TOS during the previous calculations.

LOAD n ---

Start interpretation of Screen `n`. The loading phase ends at the end of the screen or at the first occurrence of `EXIT`.
~~If `n` is negative, instead of loading from Screen# `n`, it loads text directly from stream `n` as previously OPEN# from Basic.~~
See also `-->`

LOOP a n --- (immediate) (run time)
n --- (compile time)

Used in colon definition in the form

```
DO ... LOOP
?DO ... LOOP
```

At run-time `LOOP` checks the jump to the corresponding DO. The index is incremented and the total compared with the limit; the jump back happens if the index did not cross the boundary between the loop limit minus one and the loop limit. Otherwise the execution leaves the loop. On loop leaving, the parameters are discarded and the execution continues with the following definition.
At compile-time `LOOP` compiles `(LOOP)` and the jump is calculated from `HERE` to a which is the address left by `DO` on the stack. The value `n2` is used internally for syntax checking.

LP --- a

User variable for printer purposed. In this Forth implementation it is used during compilation phase by `CASE`.

LSHIFT n1 u --- n2

Shifts left an integer `n1` by `u` bit.

M* n1 n2 --- d

Mixed operation. It leaves the product of `n1` and `n2` ad a double integer.

M*/ d1 n1 n2 --- d2

Mixed operation. Compute (`d` · `n1`) / `n2` using a "triple precision integer" as the intermediate value to avoid precision loss. This definition isn't available at startup and must be included via `NEEDS M*/`. The source file is M&%.f

M+ d u --- d2

Mixed operation. It leaves the sum of `d` and unsigned `u` as a double integer `d2`.
This definition is available after `NEEDS M+`

M/ d n1 --- n2

Mixed operation. It leaves the quotient `n2` of the integer division of a double integer `d` by the divisor `n1`.

M/MOD d1 n1 --- n2 n3

Mixed operation. It leaves the remainder `n2` and the quotient `n3` of the integer division of a double integer `d` by the divisor `n1`. The sign of the reminder is the same as `d`. This system uses floored division via `M/MOD` and implements `UM/MOD` in machine-code, `FM/REM` and `SM/MOD` as derived definitions.

MARK a n ---

`TYPE` in inverse video. This definition is not available at startup, it has to be loaded via `NEEDS MARK`.

MARKER --- (immediate) (run time)

Used outside a colon defintion in the form

MARKER cccc

this creates a new definition `cccc` that once executed restores the dictionary to the status before `cccc` was created. This removes `cccc` and all subsequent definitions. This definition allows forgetting across vocabularies since it keeps track of `VOC-LINK`, `CURRENT`, `CONTEXT` values.

MAX n1 n2 --- n3

Leaves the maximum between `n1` and `n2`.

MESSAGE n ---

Prints to the current device the error message identified by `n`. If `WARNING` is zero, a short MSG#n is printed. If `WARNING` is non zero 1, line n of screen 4 (of drive 0) is displayed. Such a number can be positive ~~or negative~~ and lay beyond block 4. See also `ERROR`.

MIN n1 n2 --- n3

Leaves the minimum between `n1` and `n2`.

MMU7! n ---

This definition accepts `n` between 0 and 223 and map the corresponding 8K-page at E000-FFFh addresses. It is coded in Assembler and uses NEXTREG A,n Next's peculiar op-code (ED 92). See `MMU7@`.

MMU7@ --- n

This definition returns a number n between 0 and 223 by asking the hardware which 8K-page is currently fitted in MMU7. See `MMU7!`

MOD n1 n2 --- n3

Divides `n1` by `n2` and leaves the remainder `n3`. The sign is the same as `n1`.

MS u ---

Waits of `u` milliseconds.
At 28 MHz, `u` must be < 8192.
At 14 MHz, `u` must be < 16384.
At 7 MHz, `u` must be < 32768.
At 3.5 MHz, `u` must be < 65536.
This definition isn't available at startup and must be included via `NEEDS MS`.
N.B. Interrupts aren't disabled during execution.

M_P3DOS n1 n2 n3 n4 a --- n4 n5 n6 n7 f

This is the NEXTZXOS call wrapper. Parameters passed on stack are used as follow:
`n1` = input parameter value for **hl** registers pair
`n2` = input parameter value for **de** registers pair
`n3` = input parameter value for **bc** registers pair
`n4` = **a** register input parameter value
`a` = service routine address

n5 = **hl** returned value
n6 = **de** returned value
n7 = **bc** returned value
n8 = **a** register
f = 0 for OK, non zero for KO.
This definition calls uses RST 08 followed by $94 to call the specified routine.
Value returned on register IX is also stored at HEX 2A +ORIGIN before IX is restored to its fixed value.

Some NEXTZXOS primitives are coded by their own as a specific definition (e.g F_OPEN, F_OPENDIR, etc), but most of them are not. For example all LAYER definitions use IDE_MODE! which in turn uses M_P3DOS.

NEEDS ---

Used in in the form:

```
NEEDS cccc
```

if the definition cccc is not present in dictionary, then it starts interpretation of text read from file **inc/*cccc*.f** and, if this is not found, gives a second chance from file **lib/*cccc*.f**

Some characters are illegal for filename: noticeably the “double-quote” character (") is among them. In such case, these characters are converted into “tilde” (~) and *that* file is then searched for.
For example:

NEEDS S" searches the file S~.f instead of an illegal filename S".f

Here is the complete map:

```
: ? / * | \ < > "
_ ^ % & $ _ { } ~
```

At the moment we are writing, this NEEDS definition has a flaw: in case of interpretation/compilation error, the file/handle remains open and you have to close it manually using something like 2 F_CLOSE .

This definition differs from INCLUDE because NEEDS cccc refers to a dictionary entry whilst INCLUDE cccc refers to a full-path filename with explicit extension.

This definition is defined as follow: Since any given Screen # n occupies **BLOCK**s n and n+1, NEEDS exploits BLOCK number 1 – which normally isn’t reachable – and uses it as a temporary buffer for each line read from file, for this reason a text source line cannot exceed 511 bytes, but for ZX Spectrum's standards is a lot more than anybody would need.

NEGATE n --- -n

Changes the sing of n1

NFA pfa --- nfa

Converts a definition’s **pfa** into its **nfa**. See also CFA, LFA, PFA, >BODY, <NAME.

NIP n1 n2 --- n2

Removes the second element from TOS. See also: OVER, DROP, TUCK, SWAP, DUP, ROT.

NMODE --- **a**

User variable that indicates how double numbers are interpreted. During the input, numbers can be read as double integer numbers or floating-point numbers. This variable is modified by the optional definition `INTEGER` that sets it to 0 and `FLOATING` that sets it to 1.

NOOP ---

This token does nothing. Useful as a placeholder or to prevent crashes in `INTERPRET`.

NOT ---

Equivalent to `0=`

NUMBER **a** --- **d**
a --- **fp** **(floating-point)**

Converts a counted string at address a with a in a double number. If `NMODE` is 0, the string is converted to double integer. Position of the last decimal point encountered is kept in `DPL`.
If `NMODE` is 1, a floating-point number conversion is tried instead of an simple double integer conversion.
If no conversion can be done, and error #0 is raised.

OCTAL ---

Changes the base to octal, setting `BASE` to 8. To use this definition you have to type `NEEDS OCTAL`.

OFFSET --- **a**

Current edit position within current screen. Used by Line-Editor.

OPEN< --- **fh**

Used in the form

```
OPEN< cccc
```

this definition invokes F_OPEN NextZXOS and opens a file `cccc`. It returns file-handle number `fh`. This definition is used by `INCLUDE`. At the moment, this definition cannot be compiled and should be used only in interpretation phase.

OR **n1 n2** --- **n3**

Executes a bitwise OR operation between the two integers. The operation is performed bit by bit.

OUT --- **a**

User variable incremented by `EMIT`. The user can examine and alter `OUT` to control the video formatting.

OVER **n1 n2** --- **n1 n2 n1**

Copies the second number from TOS and put it on the top. See also `DROP`, `NIP`, `TUCK`, `SWAP`, `DUP`, `ROT`.

P! **b u** ---

Sends to port `u` a byte `b`. Note: `u` is a 16 bit port address and an OUT (C) op-code is internally executed.

P@ **u** **---** **b**

Accepts the byte `b` from port `u`. Note: `u` is a 16 bit port address and an IN(C) op-code is internally executed.

PAD **---**

Leaves on TOS the address of text output buffer. It is at a fixed distance of 68 byte over `HERE`.

PFA **nfa** **---** **pfa**

Converts a definition's `nfa` to its `pfa`. See also `CFA`, `LFA`, `NFA`, `>BODY`, `<NAME`.

PICK **n** **---** **pfa**

Picks the **n-th** element from TOS. This means:

`0 PICK` is the same as `DUP`

`1 PICK` is the same as `OVER`

PLACE **---** **a**

User variable that holds the number of places after the decimal point to be shown during a numeric output conversion. See also `PLACES`.

PREV **---** **a**

User variable that points to the last referred buffer. `UPDATE` marks that buffer so that it is later written to disk.

QUERY **---**

Awaits from terminal up to 80 characters or until a `CR` is received. The text is stored in `TIB`. User variable `IN` is set to zero.

QUIT **---**

Clears the Return-Stack, stops any compilations and return the control to the operator terminal. No message is issued.

R@ **---** **n**

Copies to TOS the value on top of Return Stack without alter it.

R# **---** **a**

User variable that holds the position of the editing cursor or other function relative to files.

R/W **a n f** **---**

Standard FIG-FORTH read-write facility. Address a specifies the buffer used as source or destination; n is the sequential number of the block; f is a flag, 0 to Write, 1 to Read. `R/W` determines the location on mass storage, performs the transfer and error checking.

R0 --- a

User variable that holds the initial value of the Return Stack Pointer. See also `RP!` and `RP@`.

R> --- n

Removes the top value from Return Stack and put it on TOS. See also `>R`, `R@` and `RP!`.

R>DROP ---

Removes the top value from Return Stack. See also `>R`, `R@` and `DROP`.

RECURSE ---

Used only at compile-time inside a colon-definition, it compiles the definition being created to put in place a recursion call. This definition is available after a `NEEDS RECURSE`.

REG! b n ---

Writes value `b` to Next REGister `n`.

REG@ n --- b

Reads Next REGister `n` giving byte `b`.

REMOUNT ---

This definition is available only after `NEEDS REMOUNT`.
Enter the unmount/mount routine. Interactively the user is asked for a Y key-stroke, and the system waits for that key-stroke allowing the manipulation of the SD.

RENAME ---

Used in the form:

```
RENAME cccc xxxx
```

it searches the definition `cccc` in the `CONTEXT` vocabulary and changes its name to `xxxx`. The two definition names `cccc` and `xxxx` **must have the same length**. This definition is available after `NEEDS RENAME`.

REPEAT a1 n1 a2 n2 --- (immediate) (compile time)
--- (run time)

Used in colon defintion in the form:

```
BEGIN ... WHILE ... REPEAT
```

At run-time `REPEAT` does an inconditional jumt to the corresponding BEGIN.
At compile-time `REPEAT` compiles `BRANCH` and the offset from `HERE` to `a1` and resolves the offset from `a1` to the location after the loop; `n1` and `n1` are used for sysntax check.

ROT n1 n2 n3 --- n2 n3 n1

Rotates the three top elements, taking the third and putting it on top. The other two elements are pushed down from top by one place. See also `OVER`, `DROP`, `NIP`, `TUCK`, `SWAP`, `DUP`.

ROLL   n1 ... k   ---   n2 ... n1

Rotates the `k` top elements, taking the `k`-th and putting it on top. The other k – 1 elements are pushed down from top by one place. The index `k` is zero based, so that `0 ROLL` does nothing, `1 ROLL` is `SWAP` and `2 ROLL` is `ROT`.
See also `ROT`. This definition isn't available at startup, it needs to be imported via `NEEDS ROLL` .

RP!   a   ---

System procedure to initialize the Return Stack Pointer to the value passed on TOS that should be the address held in `R0` user variable.

RP@   ---   a

Leaves the current value of Return Stack Pointer.

RSHIFT   n1 u   ---   n2

Shifts right an integer `n1` by `u` bit.

S0   ---   a

User variable that holds the initial value of che SP register. See also: `SP!` and `SP@`.

S>D   n   ---   d

Converts a 16 bit integer into a 32 bit double integer, sign is preserved. An obsolete version `S->D` is still available via `NEEDS`.

SCR   ---   a

User variable that hold the number of the last screen retrieved with `LIST`.

SELECT   n   ---

Selects the current channel. As usual for ZX Spectrum, `n` is 0 and 1 for lower part of screen, 2 for the upper part, 3 for printer, 4 for "!Blocks.bin" stream. Note: `KEY` always select chanle 2 to display the (flashing) cursor.

SIGN   n   ---

If `n` is negative, it puts an ASCII "–" at the beginning of the numeric string converted in the text buffer. Then, `n` is discarded while d is kept unchanged. Used between `<#` and `#>`.

SM/REM   d n1   ---   n2 n3

Symmetric Division. Leaves the quotient `n3` and the reminder `n2` of the integer division of `d` / `n1`.
This system has only UM/MOD coded in machine-code.

Dividend	Divisor	Remainder	Quotient
10	7	3	1
-10	7	-3	-1
10	-7	3	-1

-10 -7 -3 1

SMUDGE ---

Used by the creation definition **:** during the definition of a new definition; it toggles the smudge-bit of the first byte in the nfa of the `LATEST` definition. When a definition's smudge-bit is set, it prevents the compiler to find it. This is typical for uncomplete or a not correctly ended definition.
It is also used to remove a malformed incomplete definition via

```
SMUDGE FORGET cccc
```

SOURCE-ID --- a

User variable that keeps the file-handle used during `INCLUDE` or `NEEDS`.

SP! a ---

System procedure to initialize the SP register to the address a that should be the address hold in `S0` user variable.

SP@ --- a

Returns the content of SP register before `SP@` was executed.

SPACE ---

Emits a space to the current output peripheal, usually the video. See also `SELECT`.

SPACES n ---

Emits `n` spaces.

SPAN --- a

User variable that holds the number of characters got from the last `EXPECT`.

SPLASH ---

Shows splash screen build date-number.

SPLIT n1 --- n2 n3

Split the two bytes of n1 into two separate numbers, n2 low byte, n3 high byte. Available after `NEEDS SPLIT`.

STATE --- a

User variable that holds the compilator status. A non-zero value indicates a compilation in progress.

SWAP n1 n2 --- n2 n1

Swaps the two top element at the TOS. See also `OVER`, `DROP`, `NIP`, `TUCK`, `DUP`, `ROT`.

THEN a n --- (immediate)
--- (compile time)

Synonym of ENDIF.

TIB --- a

User variable that holds the address of the Terminal Input Buffer.

TO n ---

Used in the form:

TO cccc

It assigns the value n to the variable cccc previously defined via VALUE. This definition available after NEEDS TO.

TOGGLE a b ---

The byte at location address a is XOR-ed with the model b.

TRAVERSE a1 n --- a2

Spans through the name-field of a definition depending on the value of n.
If n = 1, then a1 must be the beginning of the name-field, i.e. nfa itself; a2 is the address of the last byte of the name field.
If n = –1, then a1 must be the last byte of name-field and a2 will be the nfa.
Used by da NFA and PFA.

TRUV ---

“True video”. It disables Inverse-Video attribute mode. See also INVV.
This definition isn’t available at startup and must be included via NEEDS INVV.

TUCK n1 n2 --- n2 n1 n2

Takes the top element of calculator stack and copies after the second. See also OVER, DROP, NIP, SWAP, DUP, ROT.

TYPE a n ---

Sends to the current output peripheal n characters starting from address a.

U. u ---

Emits an unsigned integer followed by a space.

U< u1 u2 --- f

Leaves a tf if u1 is less than u2, a ff otherwise.

UM* **u1 u2 --- ud**

Unsigned product of the two integers u1 and u2. The result is a double integer.

UM/MOD **ud u1 --- u2 u3**

Leaves the quotient u3 and the reminder u2 of the integer division of ud / u1. All values and arithmetic are unsigned. An ambiguous condition exists if u1 is zero or if the quotient lies outside the range of a single-cell unsigned integer.

UNTIL **a n --- (immediate) (compile time)**
f --- (run time)

Used in colon definition in the forms

```
BEGIN ... UNTIL
```

At run-time UNTIL controls a conditional jump to the corresponding BEGIN when f is false; the exit from the loop happens if f is true.
At compile-time UNTIL compiles 0BRANCH and an offset from HERE to a; n is used for syntax checking.

UPDATE **---**

Marks as modified the most recent used buffer, the one pointed by PREV. The block contained in the buffer will be transferred to disk when that buffer is requested for another block.

UPPER **c1 --- c2**

This definition converts given character c1 to upper-case. If c1 is not between “a” and “z”, then c1 is left unchanged.

USE **---**

Used outside colon-definitions in the forms

```
USE filename
```

It tries to open filename, and if it succeeds, it closes the current BLOCKs file and uses the one just opened instead. To restore the standard/default file, you must use BLK-INIT which uses the filename given by BLK-FNAME.

USED **--- a**

User variable that holds the buffer address of the block to be read from disk or that has just been written to.

USER **n ---**

Defining definition used in the form

```
n USER cccc
```

creates an user variable 'cccc'. The first byte of pfa of cccc is a fixed offset for the User Pointer, that is the pointer for the user area. In this implementation there is only one User Area and a fixed User Pointer.
When cccc is later executed, it put on TOS the sum of offset and User Pointer, sum to be used ad the address for that specific user variable. The user variable are: TIB, WIDTH, WARNING, FENCE, DP, VOC-LINK, FIRST, LIMIT, EXP, NMODE, BLK, >IN, OUT, SCR, OFFSET, CONTEXT, CURRENT, STATE, BASE, DPL, FLD, CSP, R#, HLD, USE, PREV, LP, PLACE, SOURCE-ID, SPAN, HANDLER, HP.

VALUE **n ---**

Defining definition used in the form:

n VALUE cccc

Creates the definition `cccc` that acts as a variable. To store a value in such a variable you have to use `TO`.
When `cccc` is later executed it directly returns the value of the variable without the need to access its address using `@`.
This definition is available after `NEEDS VALUE`.

VARIABLE **---**

Defining definition used in the form:

VARIABLE cccc

creates the definition `cccc` with the pfa containing the initial value 0. When `cccc` is executed, it puts on TOS the pfa of `cccc` that is the address that holds the value.
When used in the form

cccc @

the content of the variable `cccc` is left on TOS.
When used in the form

n cccc !

the value on TOS is stored to the variable `cccc`.

VIDEO **---**

Sets `DEVICE 2` to select the video as current output peripheral. See `SELECT` and `DEVICE`.

VOC-LINK **--- a**

User variable that holds the address of a field in the definition of the last vocabulary. Each vocabulary is part of a linked-list that uses that field, in each vocabulary definition, as pointer-chain.

VOCABULARY **---**

Defining definition used in the form

VOCABULARY cccc

creates the definition `cccc` that gives the name of a new vocabulary.
Later execution of

cccc

makes such vocabulary the `CONTEXT` vocabulary, so that it is possible to search for definitions in this vocabulary first and execute them.
Used in the form

cccc DEFINITIONS

makes such vocabulary the CURRENT vocabulary, so that it is possible to insert new definitions in it.

WARM ---

Executes a warm system restart. It closes and reopens Block/Screen file then does ABORT.
It does not EMPTY-BUFFERS and you should be able to recover any transient work.

WARNING --- a

User variable that determines the way an error message is reported. If zero, only a short "MSG#n" is reported. If non zero, a long message is reported. See also ERROR.

WHILE f --- (immediate) (run time)
a n --- a1 n1 a2 n2 (compile time)

Used in colon defintion in the form:

BEGIN ... WHILE ... REPEAT

At run-time WHILE does a conditional execution based on f. If f is true, the execution continues to a REPEAT which will jump to the corresponding BEGIN. If f is false, the execution continues after the REPEAT quitting the loop.
At compile-time WHILE compiles 0BRANCH leaving a2 for the offset; a2 will be comsumed by a REPEAT. The address a1 and the number n1 was left by a BEGIN.

WIDTH --- a

User variable that indicates the maximum number of significant characters of a definition during compilation. It must be between 1 and 31.

WITHIN n1 n2 n3 --- f

Perform a comparison of a test value n1 against a lower-limit n2 and a upper-limit n3.
When n2 < n3, return a true-flag if n2 <= n1 < n3, a false-flag otherwise.
When n2 > n3, return a true-flag if n2 <= n1 OR n1 < n3, a false-flag otherwise.
This definition is available only after NEEDS WITHIN.

WORD c --- a

Reads one or more characters from the current input stream up to a delimiter c and stores such string at HERE that is left on TOS. WORD leaves at HERE the length of the string as the first byte and ends everything with at least two spaces. Further occurrences of c will be ignored.
If BLK is zero, the text is taken from the terminal input buffer TIB. Otherwise the text is taken from the disk block held in BLK. User variable >IN is added with the number of character read, the number ENCLOSE returns.

WORDS ---

Shows a list of definitions of CONTEXT vocabulary. [Break] stops.

XOR n1 n2 --- n3

Executes a bitwise XOR operation between the two integers. The operation is performed bit by bit.

ZAP ---

Used in the form

```
ZAP cccc
```

it searches for the definition `cccc` to produce a standalone executable of it by the creation of the following binary files in the current directory:

```
cccc-core.bin
cccc-user.bin
cccc-heap.bin
```

These three binary files contain the current status of the whole vForth system that can be resumed later.
You have to manually modify the basic loader "Standard-Loader.bas" in order to load these three binary files and invoke a vForth cold-start that runs `cccc` instead.
And in fact, **ZAP** modifies the definition of COLD by patching the first xt to be `cccc` and the second xt to be **BYE**.

[--- (immediate)

Used in colon defintion in the form:

```
: cccc [ ... ] ... ;
```

it suspends compilation. The definitions that follow [will be executed instead of being compiled. This allows to perform some calculations or start other compilers before resuming the original compilation with]. See also LITERAL.

[CHAR] --- (immediate) (compile time)

It is the same as the sequence `[ CHAR c ] LITERAL`.
It is used in colon defintion in the form:

```
: cccc ... [CHAR] c  ... ;
```

At compile time, `[CHAR]` compiles `LIT` and the numeric value of ASCII character `c` in the following cell.

[COMPILE] --- (immediate)

Used in colon defintion in the form:

```
: cccc ... [COMPILE] wwww ... ;
```

`[COMPILE]` forces the compilation of a definition `wwww` that is immediate. Normally an immediate definition isn't compiled but executed and to compile an immediate definition it isn't possible to use the sequence `COMPILE wwww` but it is necessary using the sequence `[COMPILE] wwww`.
For example, to create an alias `ENDIF` for `THEN` you can type:

```
: ENDIF [COMPILE] THEN ;
```

**** ---

Used in the from:

```
\ ...
```

Any character that follows \ until the end of line are treated as a comment.

] **---**

Resumes the compilation suspended by [so it is possible to continue the definition.

6.2 Case -Of structure

The following definitions aren't available at startup, it must be loaded via `NEEDS CASE`

CASE **n0** **---** **(immediate)** **(run time)**
--- a n **(compile time)**

Used in colon definition in the form

```
n0 CASE
    n1  OF  ... ENDOF
        ...
    nz  OF  ... ENDOF
    ... ( else )
ENDCASE
```

The `CASE` definition marks the beginning of Case-Of structure i.e. a set of branches where only one is performed based on the value of `n0`. If none of the “OF clause” values matches, the `ELSE` part is performed, if any.
At compile time `CASE` leaves the previous `CSP` address `a` and a number `n` for syntax checking.
`CASE` has to be balanced by a corresponding `ENDCASE`.

OF **n0 nk** **---** **(immediate)** **(run time)**
n1 **--- a n2** **(compile time)**

This definition is used in colon-definition as parto of a Case-Of structure.
At run-time it compares the matching value `nk` with the matching value `n0` that was on TOS before the beginning of the Case-Of structure.
At compile-time, it compiles `(OF)` that does a `0BRANCH` . The numbers `n1` and `n2` are used for syntax checking and an address `a` is left and used by `ENDCASE` to resolve the branch.
See also `CASE`.

ENDOF **---** **(immediate)** **(run time)**
a1 n1 **--- a n2** **(compile time)**

This definition ends an “Of-EndOf” clause started with `OF`.
At compile-time it acts like a `THEN`, first compiling a BRANCH to be later resolved by `ENDCASE` to skip any subsequent “Of-End-Of” clauses and resolving here the `0BRANCH` compiled by the corresponding previous `OF` to continue the Case-Of structure.
See also `CASE`.

ENDCASE **---** **(immediate)** **(run time)**
a a1 … az **---** **(compile time)**

This definition ends a Case-Of structure started with `CASE`.
At compile-time it compiles a `DROP` to discard the value `n0` put on TOS before `CASE` and resolves all OF-ENDOF clauses to jump after the `ENDCASE`. Finally, it restores previous content of `CSP`.
See also `CASE`.

(OF) **n0 nk** **---** **(run time)**

This definition is the run-time semantic compiled by `OF` definition. At run-time, it compares the value now on TOS `nk` with the value `n0` that was on TOS just before the beginning of the Case-Of structure and leave a flag to be used by the following 0BRANCH (that was compiled by `OF`). When `n0` equals `nk`, the definitions between `OF` and `ENDOF` will be executed, otherwise a jump to the def after `ENDOF` is performed.

6.3 Heap Memory Facility

Among ZX Spectrum Next new features is the huge amount of RAM. Strings are dictionary expensive, so it would be useful storing them in heap as constant-strings and fetch them at need. The question is how to leverage all that memory in Forth. More, 8K of room is a good place to store an array of strings, or even numeric array and implement some matrices algebra.

The definitions that handle The Heap are available after loading via **`NEEDS HEAP`**, but all low-level definitions are available in the core dictionary.

Considering how Forth's system areas are sorted out comparing previous and current versions, the first challenge is to move them down to free the top 8K CPU's addressable memory between $E000 and $FFFF allowing `MMU7` to map to any physical 8K RAM page.

There are some peculiar addresses that identify the following Forth system areas:

- $F840 : Calculator Stack (SP) grows downward, Text Input Buffer (`TIB`) upward.,
- $F8E0 : Return Stack (RP) grows downward, User Variables Area upward.
- $F94C : the `FIRST` disk buffer starts here and buffers area ends just before `LIMIT` $FF58 .

I coded this "move" in a few definitions (available in Screens #220-#223) summarized in the definition `DOWN` that moves these pointers "down" as follow:

- $FF58 → 0E000h : `LIMIT`
- $F9C4 → 0D9F4h : `FIRST`
- $F8E0 → 0D9A0h : Return Stack and User Variables Area
- $F840 → 0D900h : Stack Pointer and `TIB`

6.3.1 Heap-Pointer encoding and decoding

The Heap Memory Facility introduces a new kind of Pointer, the Heap-Pointer that represents the offset inside a virtual memory area called "heap". A Heap-Pointer is not an usual address pointer and we need a way to encode both **page number** and **address offset** in a usual Z80 16-bits integer.

Two definitions are available to perform these coding and decoding operations: **`>FAR`** and **`<FAR`** called "to-far" and "from-far" respectively.

Given a page number `n` and an address `a` (to be intended as an offset of addresses between $E000 and $FFFF, i.e. only the part of the bits are useful) **`<FAR`** definition encodes a page number in the most significant bits of **`ha`** and an offset in the remaining less significant bits. The inverse function is performed by **`>FAR`** splitting a 16-bit Heap-Pointer into two numbers again, the page part and the offset part.

In the following paragraphs a couple of possible implementations are described in detail.

6.3.2 Heap structure

The Heap can be seen as a "double linked-list" starting at 8K page $20 offset $0002. The User variable `HP` keeps the "heap-pointer" to the next available location on Heap. So, at startup, `HP` is $0002 that correspond to page $20 offset $0002. Heap space is shared with name-space dictionary.

A Heap memory allocation reserves the requested number of bytes and advances HP to point to the next available location on Heap. The previous value of `HP` is also stored at the location that was available *before* the memory allocation was requested to put in place a "linked-list".

In other words:
1. HP is advanced of one cell (2 bytes) to make room for the forward linked-list pointer.
2. Current HP value returned by the memory allocation (memory is not initialized and its content is undefined)
3. HP is advanced to the number of bytes requested (plus 2 to ensure room for 2 trailing 0x00 character).
4. HP is advanced of one cell (2 bytes) to make room for the backward linked-list pointer.

Here is a real case example:

Let **HP** contains $0F80 and the Heap memory looks as follows (Location is expressed in the form "$page.$offset")

```
Page.Address  Content
 20:0F80      .... free memory pointed by HP so that HEX HP ? gives F80
```

Then, we want to reserve a 7-bytes chunk of memory and we can type **7 HEAP** that returns $0F82 as "Heap-Pointer" to that new area of memory and HP will be advanced to $0F8D. After the execution the memory will look like this:

```
Page.Address  Content
 20:0F80      0F8D   ( forward pointer )
 20:0F82      00 00 00 00 00 00 00     ( 7 bytes just allocated )
 20:0F89      00 00                    ( trailing 0x00 )
 20:0F8B      0F80   ( backward pointer )
 20:0F8D      ....   free memory pointed by HP
```

Then we can create a new string with Heap-Storage typing **S" 123"** which returns on stack the actual address $EF90 and the length $0003 that can directly used with TYPE. The Heap-Pointer is somehow lost, and if needed, it should be kept beforehand via **HP@ CELL+**. This allocation requires ten bytes on Heap: the forward pointer, the byte of length, the string itself 3+1 byte long, a two trailing 0x00, the backward pointer.
After the execution, the memory will look like this:

```
Page.Address  Content
 20:0F80      0F8D   ( forward pointer )
 20:0F82      00 00 00 00 00 00 00     ( 7 bytes just allocated )
 20:0F89      00 00                    ( plus trailing 0x00 )
 20:0F8B      0F80   ( backward pointer )
 20:0F8D      0019   ( forward pointer )
 20:0F8F      03     ( length byte )
 20:0F90      31 32 33  ( the string content )
 20:0F93      00 00     ( plus trailing 0x00 )
 20:0F95      0F8D   ( backward pointer )
 20:0F97      ....   free memory pointed by HP
```

Then, we want to reserve another 5-bytes chunk and we can type **5 HEAP** that returns $0F99 as "Heap-Pointer" to that new area of memory and HP will be advanced to $0FA2. After the execution the memory will look like this:

```
Location      Content

 20:0F80      0F8D   ( forward pointer )
 20:0F82      00 00 00 00 00 00 00      ( 7 bytes just allocated )
 20:0F89      00 00                     ( plus trailing 0x00 )
 20:0F8B      0F80   ( backward pointer )
 20:0F8D      0019   ( forward pointer )
 20:0F8F      03     ( length byte )
 20:0F90      31 32 33  ( the string content )
 20:0F93      00 00     ( plus trailing 0x00 )
 20:0F95      0F8D   ( backward pointer )
 20:0F97      0FA2   ( forward pointer )
 20:0F99      00 00 00 00 00        ( 5 bytes )
 20:0F9E      00 00     ( plus trailing 0x00 )
 20:0FA0      0F97   ( backward pointer )
 20:0FA2      ....   free memory pointed by HP
```

Now, you should be able to see the Linked-List starting at $**0F80** that points to $**0F8D** that points to $**0F97** and then $**0FA2** is the current value of `HP`.

You can follow all these Forward-Pointers using the following procedure:

```
HEX
0F80  .S  \  Stack is 0F80 as Heap-Pointer, that is 20:0F80, the beginning of Heap Memory.
FAR   .S  \  Stack is EF80 as real Address (and page $20 is fitted in MMU7)
@     .S  \  Stack is 0F8D as Heap-Pointer
FAR   .S  \  Stack is EF8D as real Address (and page $20 is fitted in MMU7)
@     .S  \  Stack is 0F97 as Heap Pointer
FAR   .S  \  Stack is EF97 as real Address (and page $20 is fitted in MMU7)
@     .S  \  Stack is 0FA2 as Heap Pointer
```

Likewise, the Backward-Pointers sequence would be:

```
HP@  .S  \  Stack is 0FA2 as Heap-Pointer
CELL-    \  Stack is 0FA0 as Heap-Pointer
FAR  .S  \  Stack is EFA0 as real Address (and page $20 is fitted in MMU7)
@    .S  \  Stack is 0F97 as Heap-Pointer
CELL-    \  Stack is 0F95 as Heap-Pointer
FAR  .S  \  Stack is EF95as real Address (and page $20 is fitted in MMU7)
@    .S  \  Stack is 0F8D as Heap Pointer
CELL-    \  Stack is 0F8B as Heap-Pointer
FAR  .S  \  Stack is EF8B as real Address (and page $20 is fitted in MMU7)
@    .S  \  Stack is 0F80 as Heap Pointer
```

Some low-level definitions are available to allow store and retrieve “to and from” Heap memory and how to avoid that a string isn't “paged away” in the middle of processing i.e. how to guarantee a page to stay in place across Standard-ROM calls or I/O disk operations that use page-bank C000-FFFF for their purposes:

`MMU7!` is used to fit a given 8K page number at E000h (i.e. MMU7).
`>FAR` is used to decode a “16 bit pointer” splitting it into “page & offset” as shown above.

The User Variable HP has been introduced to keep track of room in Heap: it's “the pointer” to the next available space on Heap.

Most of the following definitions are available after loading via NEEDS HEAP

+" **ha --- ha**

Assuming ha is a Heap-Address Pointer to a “counted string” and this is the last chunk of memory of Heap, this definition accepts some text from the current input-source, parse it looking for a quote " that is the common “string terminator”, and appends to the previous string on Heap. It returns the same Heap-Address Pointer to a “counted string” but the “count-byte” is incremented correctly. No page boundary check is performed.

+C **ha c --- ha**

Consume a character c from the current input source and append the string being created in Heap at ha. The heap pointer ha is returned unchanged.

>FAR **ha --- a p**

Given a Heap-encoded Pointer ha this definition decodes the top bits as one of the 8K-page available page p and the lower bits as the offset from $E000 a . It does not modify what MMU7 page is.
Since version 1.7, this definition is always available. Previous versions needs NEEDS >FAR.
See <FAR, MMU7!

<FAR **a p --- ha**

Given an offset-address **a** (to be intended as a physical address between $E000 and $FFFF) and a page number **p** for an 8K-page this definition encodes the page number in the most significant bits of **ha** and an offset in the remaining bits. It does not modify MMU7 page.
Since version 1.7, this definition is always available. Previous versions needs NEEDS <FAR.
See >FAR, MMU7!

FAR **ha --- a**

This definition converts a heap-pointer ha into an offset a (at $E000) and perform the correct 8K paging on MMU7. It simply calls >FAR and MMU7!

H" **--- ha**

Accepts a text from the current input-source and stores it to Heap. It returns a “heap-address-pointer” to a counted string.

HEAP **n --- ha**

This definition reserves n bytes on Heap and returns the “heap-address-pointer”. This ha can be turned into a constant name using POINTER.

POINTER **ha --- a**

It works like CONSTANT but it returns a "FAR-resolved" offset-pointer from E000h .
A possible use is : S" ccc" POINTER P1

SKIP-PAGE n ---

Check if `n` bytes are available at the top of Heap on current 8K-page, otherwise advance `HP` to skip to the beginning of next 8K-page. It raises an "Heap Full" error if there is no more room in Heap.

S" --- a n

Accept text from the current input-source and store it to Heap as a "Counted-ZString".
At compile time it compiles **(H")** followed by an Heap-pointer just after it, which at run-time returns a real-address (at MMU7) and a counter representing the "counted-string" that can be used
If `STATE` is 0, i.e. we aren't compiling, the c

(H") --- a n

This is the run-time counterpart of **S"** that uses the Heap-Pointer in the following cell to fit the right 8K-Page in MMU7 using `FAR` definition and leave the real-address `a` and the length of the string `n`.

HEAP-INIT ---

Ask NEXTZXOS to use pages $20-$27 for Heap. From this point Heap command can be used safely.

HEAP-DONE ---

Release to NEXTZXOS pages $20-$27. Heap commands should not be used after that.

6.3.3 Heap Pointer description for 64 kiBytes space

The following solution allows 64K of physical RAM Heap: Since an 8K offset requires 13 bits, the remaining 3 bits can be used to encode, say, from page 32 ($20) to page 39 ($27). For instance:

```
                     16 bit pointer
                | pppb bbbb | bbbb bbbb |
                |           |           |
|     Page      |         Offset        |
|   0010 0ppp   | 111b bbbb | bbbb bbbb |
```

The encoding/decoding definitions would be something like the following:

```
\ >far routine
\ input:  hl : heap-pointer
\ output:  a : page
\       : hl : address starting from $E000
      ld      a,h
      ex      af,af'  ; save high part
      ld      a,h
      or      $E0
      ld      h,a     ; hl = offset at $E000
      ex      af,af'
      rlca
      rlca
      rlca
      and     $07     ; so there are eight pages
      add     $20     ; this is peculiar to this example
      ret
```

```
\ <far routine
\ input :  a : page number between 32 and 39
\       : hl : address starting from $E000
\ output: hl : heap-pointer
      and     $07     ; ? questionable: it could be SUB $20
      rrca
      rrca
      rrca
      ex      af,af'  ; keep bits 765 in alternate A
      ld      a,h
      and     $1F
      ld      h,a
      ex      af,af'   ; retrieve bits 765
      or       h
      ld      h,a
      ret
```

6.4 Testing Suite

This is an adaptation of the ANS test harness based on the work originally developed by John Hayes, see https://forth-standard.org/standard/testsuite for details.

The suite is loaded using `NEEDS TESTING` and "Core test-set" can be execute by typing

```
INCLUDE  ./test/core-tests.f
```

In general, a test is given in the form

```
T{  ...  ->  ...  }T
```

for example:

```
T{ 1 DUP -> 1 1 }T
```

TESTING ---

This definition is much like a comment, it displays the whole source line where it is.

T{ ---

Begin a test phrase that ends with `}T`. It records pre-test stack depth to be compared later.

-> ---

Record depth and contents of stack to be copared after `}T`.

}T ---

End a test phrase begun with `T{`. It compares two stack images. Any discrepancies is shown by repeating the current test SOURCE line involved followed by one of the error

6.5 Other Utilities

SHOW-PROGRESS n ---

Useful within long-lasting definitions to display a “rolling-bar” that show that your ZX Spectrum hasn’t hanged or crashed. This definition isn’t available at startup and must be included via `NEEDS SHOW-PROGRESS`.

?VOCAB ---

Useful to see which `VOCABULARY` is `CURRENT`, `CONTEXT` and the linked-list described by `VOC-LINK`.

VIEW ---

Used in the form `VIEW cccc` used to display a file. Pressing [EDIT] during ouput allows you to temporarily pause the stream of output. Pressing [BREAK] will stop the output and return to prompt.

7 The Memory Map

The memory is divided differently depending on which way vForth is started:

1. Running via dot-command, the core is loaded in DivMMC RAM at address $2000-$3FFF, and the dictionary continues at $8000. To preserve previous BASIC memory state, MMU4, MMU5 and MMU6 are fitted with 8k pages #29, #30 and #31 ($1D-$1F); heap pages from #32 to #39 ($20-$27) are fitted in MMU7 ($E000-$FFFF) when needed. I've found experimentally that, since MMU2 is extensively swapped using Layer 1,2, the content of MMU2 must be kept unchanged, so it is kept in page #40 ($28) as backup and restored on return to BASIC.
   This means twelve 8K-Pages are requested via NextZXOS call, from **#29 to #40 ($1D-$28)**.

2. Running via Basic program, the RAMTOP is lowered, the core is loaded in memory at $6366 and the dictionary continues upward in a linear way. Standard BANKS 5-2-0 configuration is used, i.e. pages $0A, $0B, $04, $05, $00, $01, with the exception that MMU7 is also used to access any 8K RAM Page other than $01.
   Eight 8K-Pages are requested via NextZXOS call, from **#32** to **#39 ($20-$27)** and fitted in MMU7 ($E000-$FFFF) when needed.

In both ways, the Name-Space part of dictionary is loaded in **BANK 16**, or to be more specific, **8K-Pages #32 ($20)** and **#33 ($21)**, then the next six Pages from **#34 to #39 ($22-$27)** are reserved as HEAP memory (§6.3) and used to keep the Name-Space along with any other HEAP objects such as long strings: this way `FORGET` and `MARKER` free memory from both HEAP and dictionary in the same call. Also, vForth should refuse to start if these page aren't available.

```
Address     Name        Description
---------   ---------   -------------------------------
0000-3FFF               ROM of Spectrum
2000-3FFF               Dot-command memory area.
4000-47FF               Display file (top)
4800-4FFF               Display file (middle)
5000-57FF               Display file (bottom)
5800-5AFF               Attribute file.
5B00-5BFF               System variables 128K RAM (former Printer buffer)
5C00-5CEF               System variables
            *CHANS      Stream map
            *PROG       Basic program
            *VARS       Basic variables
            *E_LINE     Line in editing
            *WORKSP     Workspace
            *STKBOT     Floating point Stack Bottom
            *STKEND     Floating point end
            *SP         Z80 Stack Pointer register in Basic
61FF        *RAMTOP     Logical RAM top (RAMTOP var is 23730)
6200-6300               IM2 ISR vector table (non dot-command version)
6301-6330               Return Stack during ISR (20 entries)
6331-6362               Stack area during OS operations
6363                    ISR entry point (JP address)
6366         ORIGIN     Forth Origin (non dot-command version)
                        FENCE @
             LATEST     CURRENT @ @
             HERE       DP @
             PAD        HERE 68 +  (+44h)
             ...        Dictionary grows upward
             ...        Dictionary free memory
             SP@        Calculator Stack grows downward
D0E8                    S0 @
D0E8         TIB        TIB @
             RP@        Return Stack grows downward: it can hold 80 entries
D188                    R0 @
D188-D1D8               User variables area (about 50 entries)
D1E4         FIRST      First buffer: There are 7 buffers (516 * 7 = 3612 bytes)
E000         LIMIT      First byte outside Forth.
E000-FFFF    MMU7       8K Page that can page any of the 224 banks of RAM
FFFF         P_RAMT     Phisical ram-top
```

Contents