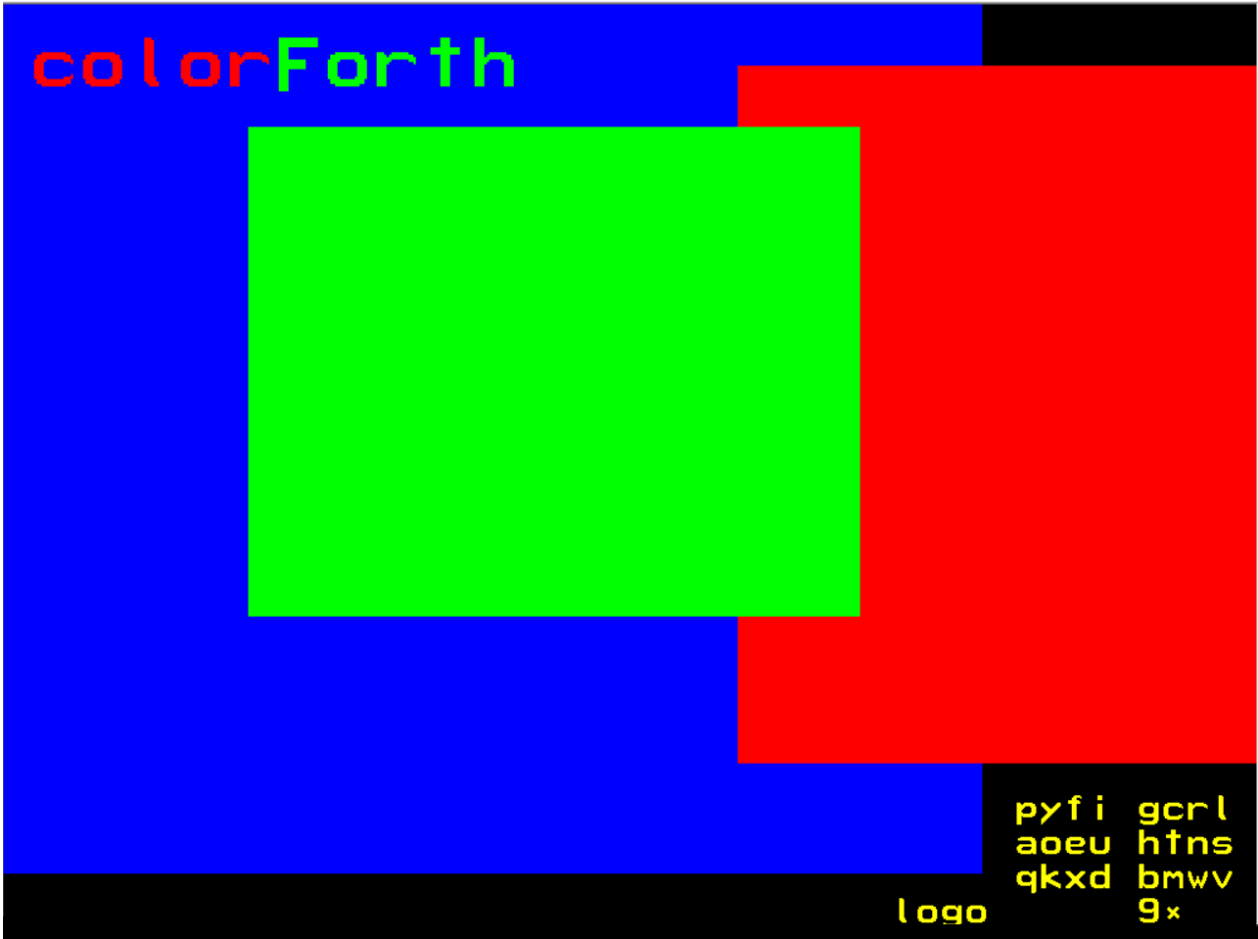


cf2022 colorForth



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Summary

colorForth is a dialect of the [Forth programming language](#), both languages were invented by [Charles H. "Chuck" Moore](#) ; - Forth around 1968, and colorForth in the late 1990's.

Click [here](#) to skip straight to the "Using colorForth" section to start having fun!

colorForth uses numbered "blocks" to store and edit its source code, rather than files. Each block is 1024 bytes in size and is paired with "shadow block", on even and odd numbered blocks respectively.

The cf2022 system is created using the file cf2022.nasm assembled by the [NASM Netwide ASSEMBLER](#), together with colorForth blocks contained in the file cf2022Ref.img .

The resulting image file cf2022.img can be run by copying it onto a USB drive (e.g.using [Rufus](#)), or in a virtual machine such as [Bochs](#), by running the Windows batch file **go.bat**.

Note that running colorForth in Bochs (version 2.6) has some differences to running natively :

1. the Processor clock counter does not work
2. the hardware Random Number Generator is not emulated
3. the Programmable Interrupt Controller cannot be re-programmed. If you run the Interrupt demo on block 256, please do not try to save the system – power down Bochs instead.

The display of the source code uses a 16 x 24 x 16 bit colour, fixed-width font, in colours that indicate the function of each word, on a 1024 x 768 pixel black background.

Keyboard entry uses a 27 key subset of a normal keyboard, these key functions are described by the "keypad display" mnemonic, seen in the bottom right-hand corner of the display. Some function keys are also used to provide compatibility with conventional systems.

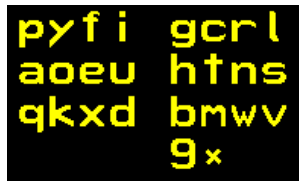


Figure 1 The keypad display

With the index fingers of each hand placed on the 'F' and 'J' keys, the keys used are that row and the rows above and below, plus the 'N', 'space' and 'AltGr' keys :

27 Keys

3 for each finger - up center down

3 for right thumb - up center right



colorForth is a concise language. The code to produce the startup logo screen pictured above is :

```
5* 5 for 2emit next ;
cf 25 dup at red $1 $3 $c $3 $a 5* green $14 $2 $1
$3 $3e 5* ;
logo show black screen 800 710 blue box 600 50 at 1
024 620 red box 200 100 at 700 500 green box text c
f keyboard ;
```

The three red words `5*` , `cf` and `logo` are new words defined in terms of the other (green) words. Newly defined words can then be used as green words in later definitions. Literal numbers may be decimal or hexadecimal, the latter being marked by a \$ symbol.

`show` sets the display task to execute the code following, using a cooperative multitasker. This allows dynamic displays which show the changing state of variables and hardware registers.

This is the documentation for the cf2022 distribution of colorForth that I maintain, distribute and publicise.

The source code and complete system (for Windows) is available from :

<https://www.inventio.co.uk/colorforth>

This is a snapshot of Work In Progress and may be subject to change in the future.

Feedback welcome : howerd@inventio.co.uk

Enjoy!

Howerd Oakford 2022 Apr 04

Colour

While the name “colorForth”, the coloured representation **colorForth** and the colourful appearance of the display all emphasise colour (spelled “color” in the USA), in fact the fundamental principles in **colorForth** go way beyond colour. Colour in this context is just one way of conveying meta-information about a computer program. For example, conventional Forth uses ‘:’ to indicate the definition of a new Forth word, colorForth uses the colour red together with starting the definition on a new line.

While conventional Forth can have coding style standards that usually specify that colon definitions start on a new line, this not required. In **colorForth**, red tokens (that start a new word definition) are displayed on a new line automatically. There are some special **blue** tokens that modify this default behaviour, and this can in any case be changed, if desired, in the NASM source code.

In the cf2022 distribution of **colorForth**, pressing the F4 function key toggles between colorForth mode and a more conventional Forth display. This is easy to do because the information and meta-information (information about the information) are stored in 32 bit tokens, and can be displayed in any desired way. The F4 function also makes it easier for people who are colour-blind to read the code.

To illustrate this, here is the code for displaying in “colour-blind” mode in a version of the editor written in **colorForth**. The first 9 lines define the colours and additional text to display for each change of token “colour” (i.e. state). The word **state!** is called immediately before each token is displayed, and compares the current and previous token colours and jumps to the correct action in the **.old** colour and **.new** colour tables defined by ‘jump’.

```

Editor Display cblind 0 260
cb cblind @ 0 + drop ; state 16 state* 16
yellow $ffff00 color ;
+txt white $6d emit space ;
-txt white $6e emit space ;
+imm yellow $58 emit space ;
-imm yellow $59 emit space ;
+mvar yellow $9 emit $11 emit $5 emit $1 emit space
;
txts string $3010100 , $7060504 , $9090901 , $f0e0d
0c , ;
tx c-c $f and txts + 1@ $f and ;
.new state @ $f and jump nul +imm nul nul nul nul n
ul nul nul +txt nul nul +mvar nul nul nul ;
.old state* @ $f and jump nul -imm nul nul nul nul
nul nul nul -txt nul nul nul nul nul nul ;
state! n-x dup 0 + drop 0if drop ; then tx cb 0if d
rop ; then state @ swap dup state ! - drop if .old
.new state @ 0 + if dup state* ! then drop then ; n
load

          SCt yrg*
          |<f>j |<↑↓>
          ab -nc+
edit      x.i

```

The same block in “colour-blind” mode looks like this:

```

] Editor Display ) [ mvar cblind 0 ] 260
: cb cblind @ 0 + drop ; [ mvar state 16 state* 16
]
: yellow $ffff00 color ;
: +txt white $6d emit space ;
: -txt white $6e emit space ;
: +imm yellow $58 emit space ;
: -imm yellow $59 emit space ;
: +mvar yellow $9 emit $11 emit $5 emit $1 emit spa
ce ;
: txts string [ $3010100 , $7060504 , $9090901 , $f
0e0d0c , ] ( ; )
: tx ( c-c ) $f and txts + 1@ $f and ;
: .new state @ $f and jump nul +imm nul nul nul nul
nul nul nul +txt nul nul +mvar nul nul nul ;
: .old state* @ $f and jump nul -imm nul nul nul nul
nul nul nul -txt nul nul nul nul nul nul ;
: state! ( n-x ) dup 0 + drop 0if drop ; then tx cb
0if drop ; then state @ swap dup state ! - drop if
.old .new state @ 0 + if dup state* ! then drop the
n ; [ nload ]

```

SCt	yrq*
←f→j	←↑↓→
ab	-mc+
edit	x.i

If you are familiar with conventional Forth you will recognize the ‘:’ (red) as the start of a new word definition, the ‘(’ and ‘)’ brackets to define (white) comments and the ‘[’ and ‘]’ square brackets to wrap “immediate” (yellow) words.

The ‘mvar’ word represents a [magenta variable](#), an interesting feature that is easy to implement in colorForth. When executed, a magenta variable returns the address of the next 32 bit cell in the source code block. If a value is stored into a magenta variable the source code is effectively changed, and due to the dynamic update of the display task the new value will be seen immediately on the screen.

Token Colours

The following colours and their meaning is described below, from file cf2022.nasm line 4024 :

```

actionColourTable:      ; * = number
dd colour_orange        ; 0 extension token, remove space from previous word, do not change colour
dd colour_yellow        ; 1 yellow "immediate" word
dd colour_yellow        ; 2 * yellow "immediate" 32 bit number in the following pre-parsed cell
dd colour_red           ; 3 red forth wordlist "colon" word
dd colour_green         ; 4 green compiled word
dd colour_green         ; 5 * green compiled 32 bit number in the following pre-parsed cell
dd colour_green         ; 6 * green compiled 27 bit number in the high bits of the token
dd colour_cyan          ; 7 cyan macro wordlist "colon" word
dd colour_yellow        ; 8 * yellow "immediate" 27 bit number in the high bits of the token
dd colour_white         ; 9 white lower-case comment
dd colour_white         ; A first letter capital comment
dd colour_white         ; B white upper-case comment
dd colour_magenta       ; C magenta variable
dd colour_silver        ; D
dd colour_blue          ; E editor formatting commands
dd colour_black         ; F

```

Actions, not Words

I strongly recommend that you run cf2022 as a program on a suitable computer. There are two ways of doing this :

1. Copy the binary image file cf2022.img directly onto a USB drive, and boot the computer using this drive.
2. Run cf2022 in a bochs environment under Windows. Double click on the file **go.bat** in the cf2022 distribution to do this.

This is because “the map is not the territory” – both Forth and colorForth provide an interactive environment that is best experienced, rather than discussed or thought about.

Using colorForth

Note : The space bar is used in colorForth as if it is the Enter key.

The system starts up in the Editor - press the space bar to exit, then the space bar again to enter numeric mode.

Enter a number and press the space bar again. Press the space bar again and enter the next number. After entering two numbers e.g. '1 1' press the AltGr key to see the Alternative alpha keypad, and press '+':

1 1 +

```

colorforth cf2022 2022 Apr 08
processor clock mhz 4
dump x 5952 y 0 ld blk 64
2 12 +thru
dump 78 load ;
icons 80 ld ;
north 92 ld ;
lan 98 ld ;
wood 106 ld ;
sound 114 ld ;
eth 176 ld ;
ed 252 ld ;
int 288 ld ;
info ver dump ;
serve 506 ld ;
rtc 96 ld ;
colors 102 ld ;
mand 108 ld ;
gr 118 ld ;
life 272 ld ;
slime 246 ld ;
xx 278 load ;
staks 504 ld ;

hardware rng 0
chm -- 0 mhz ! $1740 x ! 0 y ! 64 blk ! $10000
ch n-- 64 block swap md5 dump ;
hlp randq rng ! logo pause calkhz
    onsec @ 1000 / mhz ! e ;
mark empty hlp

Press the * key to see the comment block
Press F1
1 1 123
::!@ 123
zj., 4560
*/+- 789?
+ x.a

```


Above shows the state just before the final space bar. The '123' represents the current word being typed, in this case '+'. The two '1's are on the stack, with the current word being typed, and the stack is shown in the bottom left of the screen. The orange '64' in the top right is the current block number.

Pressing the space bar now will execute '+' which adds the top two stack items, in this case '1' and '1', and will return '2'.

On a running cf2022 system :

Press F1 for the help screen. Press repeatedly to cycle round the main load block and its documentation shadow block.

Press F2 to toggle decimal and hexadecimal display of numbers.

Press F3 to toggle display or hiding of blue token words. These words may be added or deleted like any other word in the editor. The following special blue words are detected and acted on by the editor display :

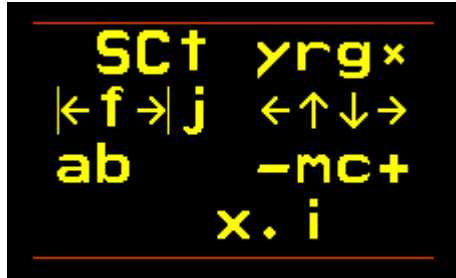
Blue word	Function
cr	one CR
,	one CR
-tab	move to the next 24 multiple column, disabling a CR for a red word
tab	move to the next 24 multiple column
br	two CRs
-cr	disable a CR for the next red or magenta word
cr+	one CR and indent 3 spaces
blue	no action
tab3	align to next 3 space column
.	add one space
..	add two spaces
...	add three spaces
....	add four spaces

Press F4 to toggle normal and "colour-blind" display mode, also runs the editor.

Press F6 to toggle between the current and last edited block.

The colorForth Editor

When the editor is run by typing **e** , **256 edit** , or by pressing F4, the keypad looks like this :



The mnemonics mean :

Mnemonic	Function	Qwerty key (UK)	Qwertz key (German)
S	White text CAPITALS	W	W
C	White text first letter only Capital	E	E
t	White text lower case	R	R
y	Yellow – immediate actions, not compiled	U	U
r	Red token – create a new word	I	I
g	Green – compiled token	O	O
*	Toggle main and shadow blocks	P	P
j	Jump to last edited block	F	F
l u d r	Cursor arrows, left up down right	J K L ;	J K L Ö
a	Silver (gray) token	Y	Y
b	Blue token	X	X
-	Decrease block number by 2	M	M
m	Magenta variable token	,	,
c	Cyan	.	.
+	increase block number by 2	/	-
x	Delete token	N	N
.	Exit the editor	Space bar	Space bar
i	Insert previously deleted token	AltGr	AltGr
-left-arrow	Find previous token name RSN	A	A
f	Find token name RSN	S	S
-right-arrow	Find next token name RSN	D	D

- RSN = Real Soon Now...

Use the + and - keys to select the block to edit (also PgUp and PgDn), or press the space bar to exit the editor and type

256 edit to edit block 256

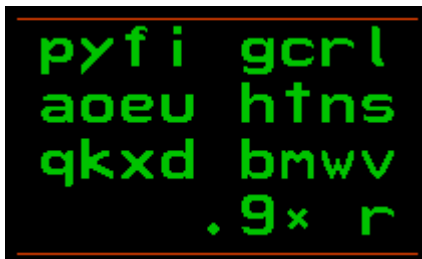
Use the l u d r arrow keys to move the cursor to the required location. The arrow keys and the Home and End keys can also be used to move the cursor.

Choose a colour, for example red to create a new word – the keypad now looks like this :



Press the required letters until you have finished entering the word, then press the space bar ('9').

The display then turns green to enter a word to be compiled :

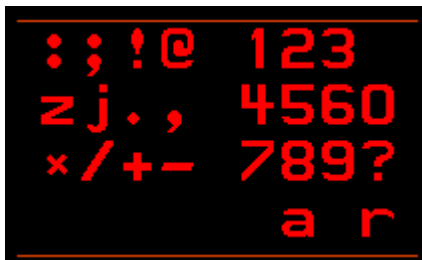


Press the required letters until you have finished entering the word, then press the space bar ('9').

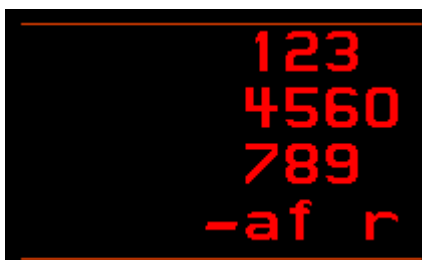
Repeat for the next word.

If you press the N key ('.') you will return to the main Editor keypad, so you can choose a different colour, move the cursor or select a new block to edit.

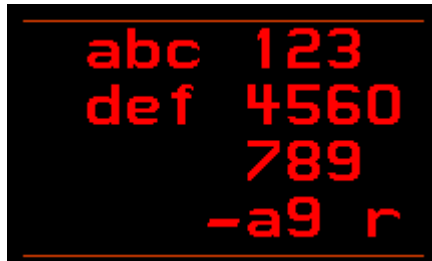
The AltGr key, labled * in the keypad toggles between the main alpha and Alternate alpha text entry mode :



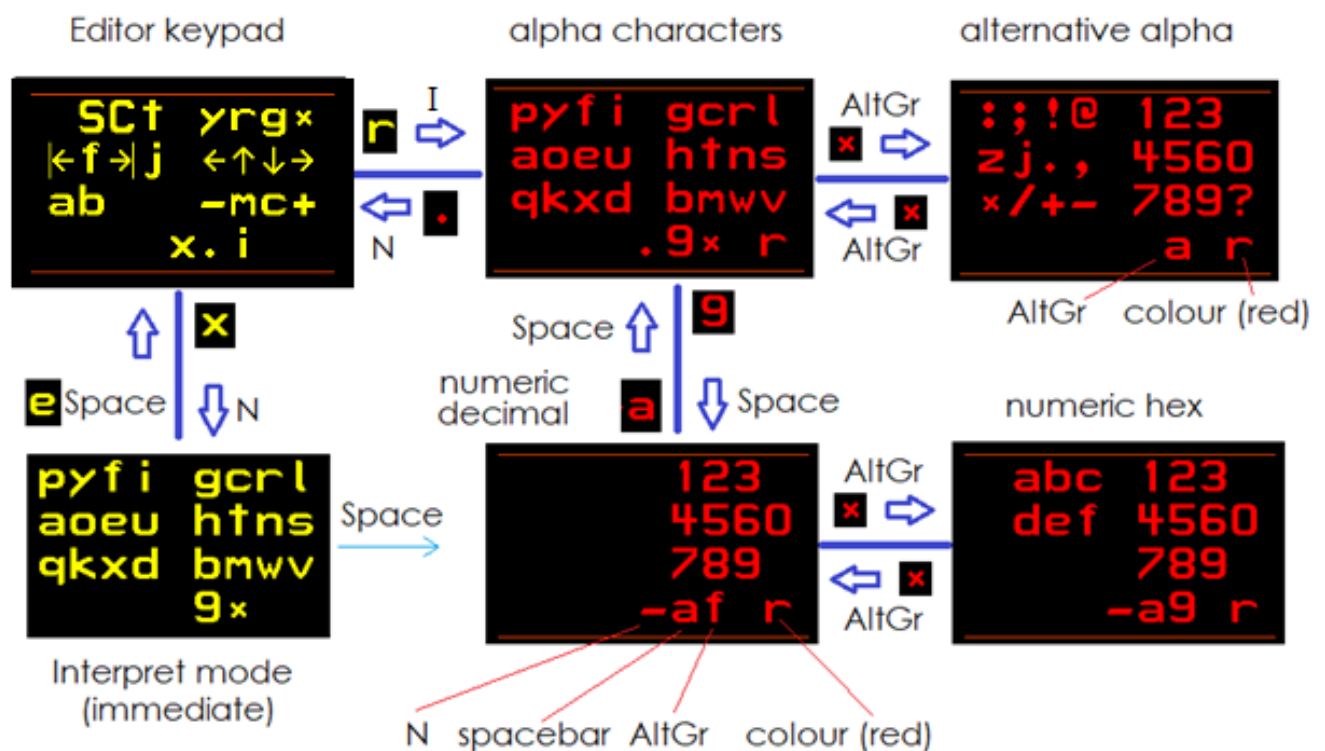
Press the required letters until you have finished entering the word, then press the AltGr key to return to alpha mode, then the space bar ('9') as described above.



Pressing the space bar in alpha mode will change to numeric mode, pressing the AltGr key toggles between decimal and hexadecimal display mode :



The following diagram show the different keypad mnemonics and the keys to press to change them :



The other colours, and Editor / Interpret mode all have similar functionality.

Editor mode is shown by the two horizontal lines above and below the keypad.

When you have found and/or edited the block that you would like to run, leave the editor by pressing the space bar. You are now in Interpret mode (no more horizontal lines).

Type the command you would like followed by the space bar.

colorForth and ASCII

The colorForth keypad has only 48 characters – this edition allows three ASCII (or UTF-8) characters to be encoded into a standard colorForth 32 bit token. This increases compatibility with other Forth systems.

```
; ASCII / UTF8 support. If the first Shannon-Fano encoded letter is a 4 bit NULL,  
; display the next 24 bits as three ASCII characters.  
; $03e3c009 is displayed as '>>'
```

```
Sandbox >< any old ASCII <=> 510
test your code here ;
```

SCt yrg*
<f>j <↑↓>
ab -mc+
x.i

```
82b60c6a 0008f800 jg7 Sandb
3ca00000 0008f804 ox
03e3c009 0008f808 ><
56980009 0008f80c any
3a600009 0008f810 old
5849dc0b 0008f814 ASCII
03c3d3e9 0008f818 <=>
24810003 0008f81c test
99e61004 0008f820 your
91e04004 0008f824 code
c8828004 0008f828 here
f0000004 0008f82c ;
00000000 0008f830
00000000 0008f834
00000000 0008f838
00000000 0008f83c
```

jg7 >< any old ASCII <=> test your code here ;

pyfi gcrl
aoeu htms
qkxd bmwv
dump 9x

cf2022.nasm ASCII Support code

This is the code to support decoding and display of ASCII characters.

```

lowercase:    ; display a white text word in normal lower-case letters
    call white
showSF_EDI_:  ; ( -- ) \ display a Shanon-Fano encoded token pointed to by edi in the
current colour
    _DUP_
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]    ; fetch the next token - drops through to
showShannonFano

showShannonFano:    ; ( token -- ) \ display the Shannon-Fano encoded token on TOS
    ; ASCII / UTF8 support. If the first Shannon-Fano encoded letter is a 4 bit NULL,
    ; display the next 24 bits as three ASCII characters.
    mov _SCRATCH_, _TOS_                ; save the token value
    and _SCRATCH_, 0xF0000000
    cmp _SCRATCH_, 0x00000000
    jnz .forward
    ; display as three ASCII characters
    mov _SCRATCH_, _TOS_

    mov _TOS_, _SCRATCH_
    shr _TOS_, 20
    and _TOS_, 0x000000FF
    jz .null_terminator
    _DUP_
    call emit_

    mov _TOS_, _SCRATCH_
    shr _TOS_, 12
    and _TOS_, 0x000000FF
    jz .null_terminator
    _DUP_
    call emit_

    mov _TOS_, _SCRATCH_
    shr _TOS_, 4
    and _TOS_, 0x000000FF
    jz .null_terminator
    _DUP_
    call emit_

    ; arrive here if an ASCII character is an ASCII NULL, or if all three have been
emitted
    .null_terminator:
    call space_                ; display a space character at the end of the word
    _DROP_
    ret

.forward:

    ; display as Shannon-Fano encoded token name
    and _TOS_, byte -0x10    ; and _TOS_, 0xFFFFFFFF0 ignore token colour when displaying
the letters

lowercasePrimitive: ; ( token -- ) \ display the given Shanon-Fano encoded word in the
current colour
    call unpack
    jz lowercasePrimitiveEnd
    call emitSF_
    jmp lowercasePrimitive
lowercasePrimitiveEnd:
    call space_
    _DROP_
    _DROP_
    ret

```

Useful Commands

Command	Action
e	Run the Editor displaying the last block edited
64 edit	Run the colorForth Editor displaying block 64
xx	Run the colorForth Explorer
ll	Load the current block displayed by the Editor
vv	View the last block loaded by the command ld
uu	Undo all changes to the current block
ss	Save the current block to disk
save	Save the entire system to disk. You can change the USB stick to save a backup.
sa	Save and return to the Editor
logo	Show the colorForth logo screen
empty	Remove all compiled definitions since mark was called
mark	Mark the current system state for empty
\$1000 dump	Dump the 16 32 bit cells starting at address \$1000
bye	Exit the system, discarding all edits since the last save, sa or ss
hlp	Update the hardware system info and display the start block. This is currently block 64, and displays a list of Apps.
life	Run the Conway's Game of Life demo. Press the space bar to exit (marked by a '.' In the keypad mnemonic), then type xx and press the space bar. Scroll to "Conways Game of Life" and press the e key to view the source code, then press the '*' key in the Editor to view the documentation shadow block.
staks	Display the four task's stacks. 'U' means Unused, '.' means used. Checks that the stacks are not growing or shrinking...

You can also use the cursor control keys in the editor or the arrow, Home and End keys to move the cursor immediately after a red word (in either Editor or Interpret mode), then press the Enter Key (on the QWERTY or QWERTZ keyboard, not the keypad) to execute that word.

History

Micro Forth

I discovered Forth, in the form of Micro Forth for the RCA CDP1802 processor chip, around 1979.

I was working for a small startup company in the UK, developing a Grain Moisture Meter, and was planning to use the RCA CDP1802 assembler. When I unpacked the newly arrived RCA COSMAC development system (an 8 bit CDP1802 processor clocked at 2 MHz, with 4K RAM) I noticed a single sheet of paper advertising MicroForth, and promising fast development times, small code size and fast run-time speed - all of these claims I later found out to be true.

Having convinced my boss that Micro Forth would be a good investment, I waited for some weeks for the 8-inch floppy disk to arrive by post from California, and followed the Quick Start Guide.

I typed `1 1 + .` and saw the result `: 2 .` I could talk to the computer, and it could reply, and it could even do maths. I was impressed, and at that moment my career as a computer programmer changed direction to the Forth side – I was hooked.

polyForth and chipForth

Having completed the Moisture Meter project, in the mid 1980's I looked for more Forth work, and got contracts working for COMSOL in the UK (a Forth software development house and supplier of Forth, Inc. products such as Micro Forth, polyForth and chipForth). It was through COMSOL that I got a job working on the Riyadh Airport HVAC system, for AVCO in Huntsville Alabama.

Slowing down for C

Towards the end of the 1990's the demand for Forth had diminished, so I learned C. My first C contract was a six month project – when I discovered the details of the contract I was **horrified** – in Forth, I would normally have finished this sort of project in 6 weeks.

As I polished my C/C++ and later C# skills I found that it was not good etiquette to mention Forth at work, especially at interviews. In every big company, maybe 1 in 50 programmers would say something like “Oh yes, I used Forth back in the 80's – loved it!”. And an equal number of people would look at me like I had escaped from a lunatic asylum, retro-computing museum or Area 51 UFO containment area. So I went into [stealth mode](#) – I kept “[...one of the best-kept secrets in the computing world](#)” to myself. It seems that software development departments encourage programmers to use their own tools, so I rarely had problems using Forth to develop “tools”, even when the ultimate goal was to develop C or C++ programs.

This gave me an overall speed advantage of maybe 2 or 3 times compared to my colleagues – this resulted in long, relaxed contracts in C, interspersed with much shorter contracts in Forth.

ANS Forth and Windows

With Windows replacing MSDOS, I started using SwiftForth (Forth, Inc.'s product for Windows), MPE's VFX Forth and Win32Forth. Forth is a chameleon language – it adapts to its environment, in this case Windows.

I do not hate Windows, in fact I think Microsoft have produced products of a consistently high standard, at least since NT4. But Windows programming has become steadily more and more difficult. Using Forth I still have an advantage over my colleagues – my “secret weapon” is still loaded and ready for action.

colorForth

Around 2001 I downloaded Chuck Moore's public domain colorForth from his website and copied on to a 3.5 inch floppy disk. It was not easy to get working – I had to add a new, compatible floppy disk ISA board to make it work.

I was impressed, again, wrote the article : [colorForth and the Art of the Impossible](#) and presented it at [EuroForth 2001](#). I also had the great good fortune to spend about 45 minutes with Chuck, looking at his colorForth CAD system, OKAD II.

I love working in colorForth – I think it must be something genetic, certainly it appears not to be curable.

I presented another paper at [EuroForth 2003](#) "[The colorForth Magenta Variable](#)", and handed out floppy disks with the first distribution of my version of colorForth.

Time marches on, and one of my two PCs still with a floppy disk drive, died. I still have the other one, in the cellar, "just in case". But it became obvious that colorForth needed to be updated to run from a USB stick.

A decade or so later, I presented a paper "[Crypto colorForth](#)" at [EuroForth 2017](#) (the video is [here](#)), and demonstrated colorForth running from a USB stick. I believe that security and complexity are incompatible in computer software, and that colorForth can be the basis of a very secure operating system (without using files).

Today I am launching colorForth cf2022 – there are a lot of changes, most of them for the better :

The font is now in ASCII order, even though Shannon-Fano encoded names are still used internally.

Byte addresses are used throughout, all magic numbers have been replaced by equ's and the code is now better documented. It is far from perfect.

The user experience is more comfortable, most of the original apps now work again.

The Future

1. Make colorForth load and run from a FAT32 file system on a USB stick. I already have a FAT32 single sector bootloader. This will allow data transfer between the colorForth system and the rest of the world.
2. Add more drivers for Ethernet and WiFi hardware and mouse support.
3. Add an assembler/disassembler and the ability of colorForth to rebuild itself without NASM.
4. Add a secure data/metadata sharing and backup system (the [You-Me Drive](#))

Philosophy

Keep it simple

From Chuck Moore's book [Programming a Problem-oriented Language](#) :

"The Basic Principle

• *Keep it Simple*

As the number of capabilities you add to a program increases, the complexity of the program increases exponentially. The problem of maintaining compatibility among these capabilities, to say nothing of some sort of internal consistency in the program, can easily get out of hand.

You can avoid this if you apply the Basic Principle.

You may be acquainted with an operating system that ignored the Basic Principle. It is very hard to apply. All the pressures, internal and external, conspire to add features to your program.

After all, it only takes a half-dozen instructions; so why not? The only opposing pressure is the Basic Principle, and if you ignore it, there is no opposing pressure."

Chuck Moore from Fireside chat Nov 2020

<https://www.youtube.com/watch?v=81bklqPpe0g> 34:33

Sean: Why do you think Forth has failed to go mainstream?

Chuck: I used to think about that a great deal.

I think that what happens in the world is largely a matter of luck, unpredictable, unrelated to quality or cost - it's just a fad, and some fads stick, and some fads don't.

I don't think that there is any need for Forth to become a mainstream language.

I think it is a very excellent niche language, and a personal language.

It can be used to advantage by people like us, without requiring that the whole world give us permission.

The Maze Effect

My own experience of writing computer software is that it is like traversing a maze, rather than travelling a well mapped journey. It is often the case that you get to within one hedge-width of the goal, only to find that there is no way through – you must back-track, re-think and repeat . This equates to discarding already written software, which is often interpreted in a commercial software development environment as an expensive mistake, and so must be avoided.



Figure 2 The Hedge Maze at Longleat, UK

The picture above shows a hedge maze – a good metaphor for real-world software development. You can also see here bridges that can be used to climb over hedges – the one in the foreground could represent the change from block-based to file-based source code. Clearly it is an enormous advantage if you want to go in that direction, but it can also prevent or hinder access to other goals. It is not clear in the above picture precisely what the goal is, and this often goes for software development.

It is very difficult to write a requirements specification for a system that has not yet been discovered.

Operating Systems and the Free Market Economy

In the developed world, commercial companies exist to make a profit – it is illegal to run a company that makes a loss – therefore there are two areas where “due diligence” must be applied :

1. Maximizing profit
2. Assessing risk

In the field of software development, maximising profit can be approximated to maximizing sales, if the development cost is (or can be made to be) a fixed amount.

Microsoft, for example achieved success initially by selling the MSDOS operating system. The “killer idea” was to sell a program to hardware manufacturers that provided a smooth interface to programs written by software developers. An entire eco-system evolved in which everybody gained :

1. hardware manufacturers sold more because their product could run more programs
2. software developers could sell more software because it could then run on more hardware
3. Microsoft made a huge profit

When competitive Operating Systems (OS's) came along, it became necessary to “Lock in” users.

A number of techniques have been used :

1. Operating Systems must be complex, otherwise everyone can write their own
2. The interface must be incompatible with other OS's
3. Metadata must be held outside of the users' control

It is the last item that I wish to explain in more detail, and then confront :

Metadata and Files

What is a *file*, where does it exist and who owns it?

Take as an example a file in the MSDOS or Windows Command Shell environment. Typing CD shows you the current folder, typing DIR lists the files in that folder. This gives the illusion that your file exists in that folder – you can see it, send it, open it, edit it etc. The file content, and the directory structure where it can be found may well exist on your computer – you can delete it after all, and its gone (or at least it has been moved somewhere else).

But the metadata (information about the file) can only be accessed through the Operating System – that is what the Operating System is for, after all.

Take another example :

I create a Word document using Windows and the Word app. I send it by TCP/IP to a colleague who opens it on an Apple computer using the MAC OS and Pages. The most important metadata of the file is its size. The TCP/IP programming interface requires an address of the file data and its length. The Windows file system provides these parameters to the TCP/IP program, the required amount of data is sent to the Apple computer, and its TCP/IP program passes the data to the MAC OS.

Note that the metadata (file size) is not attached to the file at any point. Certainly the TCP/IP program requires and supplies a length parameter, but it is not attached to the file.

Of course both Operating Systems provide a convenient user interface, but the users are locked-in.

Another protocol layer is required – for example [SMB or SAMBA](#) - and these layers can be made as complex and incompatible as is required to prevent another Operating System from competing easily.

There are many data exchange formats, for example [XML](#) and [JSON](#) – but these describe the data content of files and are not an alternative to files.

An important part of lock-in is never to attach important metadata such as the filesize to a standardised data structure. This is to prevent simple applications from using the “file” without being tied to a complex Operating System.

The Library Trap

Forth and colorForth provide an interactive environment, in which maze-traversal becomes an order of magnitude faster (and more enjoyable) than non-interactive, batch processed languages such as C/C++/C# - IMHO, YMMV.

Python also provides an interactive environment, with libraries - for certain classes of problems it is an extremely effective tool – I have used it for example to create AES128-GMAC signed packets for testing software. Protocols such as AES and GMAC are complex, maybe necessarily so for signing packets securely, and this certainly saved many weeks of work.

There are at least two problems with libraries :

1. As implemented in Python they come with a lot of baggage - an Operating System, installer programs - and of course Python interprets files - not exactly KISS.
2. One of the fundamental principles of both Forth and colorForth is that the user and computer develop a relationship – the user teaches the computer how to do new things by defining new words, and the computer tells the user what it thinks of these new words, by returning values and error messages. Libraries do not allow this interaction. Somebody else may have experienced this when the library was written, but now it is just code.

The Polarizing Effect

IMO Forth is a polarizing language because it can dramatically increase productivity in software development. This has several effects :

1. Non-Forth programmers feel uncomfortable when a Forth programmer produces a program in a half or a quarter of the time that they would take. Nobody likes to be made to feel like an idiot.
2. Forth programmers have a significant advantage, so they naturally love [“...one of the best-kept secrets in the computing world.”](#)
3. Programming in Forth is fun – it is creative rather than mechanical work
4. Forth is different and can have a steep un-learning curve

So people either love Forth or hate Forth – there is wide distance between the two extremes.

An anecdote :

In the late 1990's I was working on a three month contract, programming an LCD driver in C.

There were four special constraints :

1. The interface was I2C and the power consumption was critical, so only the minimum information must be sent, that is required to update the LCD
2. There were two LCD driver chips, one for the left half of the display, the other for the right
3. The whole display is mounted upside down – the graphics mode x,y = (0,0) coordinate is in the bottom right hand corner (instead of top left).
4. The 8x8 character glyphs have to be rotated by 180 degrees.

The interface is similar to ANS Forth's TYPE and AT-XY, but in C.

To solve this problem I first added a simple talker program, written in C that connected the devices serial port to its I2C bus and memory - something like PEEK and POKE, I2Cread and I2Cwrite.

Then I used SwiftForth to create the other side of the talker interface and words to display characters and the memory map in the device that was used to store the current LCD data. I also a word to rotate the font data and save it as a C file.

Having developed the program in Forth on a PC, testing all the while on the actual ARM target device, I translated the Forth program to C. Since I knew that I would be doing this I did not use any fancy Forth features such as CREATE DOES> or EVALUATE , and I kept the Forth word names compatible with C – no “%&*+-. ><” etc. characters.

The timescale for this was roughly three weeks of fun Forth development, about a week to convert to C. Then I cleaned up the code a bit, improved the documentation and so on, and after about 6 weeks I presented the finished code to my colleague – an experienced and competent C programmer. He was surprised that I had completed the work so quickly, but was embarrassed that I had shown that his original time estimate was so wrong. No one likes to feel that they are inferior to anybody else, or that their career based on C is maybe not the most productive. My contract was not extended.

colorForth Under the Hood

BIOS disk access

Originally using direct hardware access to Floppy disk controller hardware, now converted to use 16 bit BIOS calls from 32 bit protected mode. This means you can use a USB stick, or USB Floppy drive.

Video Display

The display setup uses VESA calls, 1024x768 16 bit colour mode, with some support for 800x600 16 bit colour. I did this was so that I could run colorForth on my Samsung NC10 netbook.

Keyboard

The keyboard keys are scanned directly from I/O ports, using a PAUSE in the wait loop. Luckily the BIOS handles a USB keyboard and emulates legacy hardware ports.

Keypad

colorForth does not use the keyboard in the usual way, but instead uses any type of 102 key keyboard to emulate a [27 key keypad](#), along the lines of a Dvorak keyboard.

Appendix A Chuck Moore's colorForth Primer

colorForth Primer

Chuck Moore

colorForth is a uniquely simple way of programming computers. It is particularly suited to the multi-computer chips of GreenArrays. How simple it is:

Words

colorForth uses words much as English does. (A *word* can be a subroutine, if that helps.) A *word* is a string of lower-case characters (from a set of 48) ending with space. The character @ is pronounced *fetch* and fetches a number from some address. Likewise, ! (*store*) stores a number. Some words:

- and or drop dup over push pop
- for next unext -if if then
- ; @ ! @+ !+ @b !b @p !p
- + . +* 2* 2/ - b! a!
- 12345 -1 144 0

If you type a **word**, the computer will perform some action. For example

- **on**

might turn on a light.

Numbers

Words that look like numbers are placed on a push-down stack (like a stack of dishes). @ also puts numbers on the stack. There they serve as arguments for later words:

- 1000 ms
- 3 !

Definitions

New words are defined in terms of old:

- **toggle** on 1000 ms off ;

The red word is defined by the following green words. When you type **toggle**, the light is turned on, the computer waits 1000 ms (milliseconds) then turns it off. Semicolon marks the end of this word (return from subroutine).

Other words:

- **on** 3 !;
- **off** 2 !;

Here a number is stored into a register to change an output.

Loops

Computers are good at repetition. Here's one way to define a loop:

- **ms** for 1ms next ;

The word **for** expects an argument and puts it into a counter. The word **next** returns to **for** that many times. The word **1ms** waits 1 millisecond.

Conditions

Computers sometimes need to make decisions:

- **abs** -if - 1 + then ;

abs will return the absolute value of its argument. If it is negative, **-if** does a ones-complement and adds 1. If it is not negative (positive or 0) **-if** jumps to **then** and does nothing.

Compiler

colorForth compiles source code into machine instructions, which can then be executed. It uses color to indicate the function of a word:

- **Yellow** - a word to be executed
- **Red** - a word being defined
- **Green** - a word to be compiled as part of a definition
- White (or black) - a comment to be ignored

Color aids understanding, avoids syntax and simplifies the compiler.

The compiler reads words from text stored in memory. A special editor manages this text. **colorForth** code is exceptionally compact.

Program

A program in colorForth is a collection of simple words that describe a task. Although definitions can be long and complicated, that is not wise. A larger number of simpler words is easier to read, write, debug and document.

The computer begs fallible programmers: Keep It Simple, Stupid (KISS). colorForth helps.

Appendix B NASM Source Code

```

Q
; cf2022.nasm 2022 Sep 24 MD5 9fe7e198347e027576a65d1289f561a0 "sitar-flatfish"
; "chm" ( check MD5 )in colorForth shows "W" and "$ef18ce" and "get,m"
; colorForth for 80x86 PC for NASM , with 1024x768 and 800x600 graphics options
; Adapted by Howerd Oakford from code by :
; Chuck Moore : inventor, MASM
; Mark Slicker : ported to GNU Assembler
; Peter Appelman : ported to NASM with qwerty keyboard
; Josh Grams : multitasker
; John Comeau : BIOS boot from ClusterFix
; 2drop and 2dup bug fix from Marco Nicola
; and others... Thanks to all!!!
; Feedback welcome : howerd@inventio.co.uk www.inventio.co.uk

; %define NOT_BOCHS      Bochs cannot handle resetting of the PIT chips, so we can optionally disable this

; CPU 386 ; Assemble instructions for the 386 instruction set

%define FORCE_800x600_VESA 0      ; true to force 800 x 600 x 16 bits for testing in bochs

%define START_BLOCK_NUMBER      64 ; must be an even number. Note: if you change this you must shift the
blocks in cf2022Ref.img accordingly!

%define SIZE_OF_FONT_IN_BLOCKS 12
%define OFFSET_OF_FONT         ( ( START_BLOCK_NUMBER - SIZE_OF_FONT_IN_BLOCKS ) * 0x400 )
%define LAST_BLOCK_NUMBER      511 ; must be an odd number

%define SECTORS_TO_LOAD ( ( LAST_BLOCK_NUMBER + 1 ) * 2 ) ; number of 512 byte sectors

%define BITS_PER_PIXEL 16 ; MUST BE 16 !!! display pixel sizes, colour depth = 16 bit ( 2 bytes )

; for the maximum supported screen : 1024 x 768 pixels :
%define MAX_SCREEN_WIDTH ( 1024 ) ; maximum screen width in pixels
%define MAX_SCREEN_HEIGHT ( 768 ) ; maximum screen height in pixels

%define BYTES_PER_PIXEL ( BITS_PER_PIXEL / 8 )

PIXEL_SHIFT equ 1 ; how many bits to shift to scale by BYTES_PER_PIXEL

; Memory Map
; start length
; 0x100000 .... RAM
; 0xC0000 0xFFFF BIOS video ROM - its not RAM!
; 0xB8000 0x08000 BIOS video RAM
; 0x10000 0xA8000 cf2022.img file is copied here
; 0x0F000 0x01000 BIOS shadow RAM - its OK to use this if we do not call the video BIOS
; 0x0A000 0x05000 BIOS video RAM - do not use until we have changed video mode
; 0x07c00 0x00200 BPB Boot sector after loading by BIOS
; 0x07c0b <----- di points here, the BPB ( + offset ) and variables ( - offset ) are accessed via [di]
; 0x07b8c 0x00080 variables referenced via [di], followed by BPB variables referenced via [di]
; 0x07800 Stacks, size = 0x0200 each , growing downwards
; 0x02000 0x06800 SECTOR_BUFFER
; 0x00000 0x02000 BIOS RAM

%define SECTOR_BUFFER      0x00002000 ; buffer for disk reads and writes
%define SECTOR_BUFFER_SIZE 0x4800 ; 18 K bytes, 36 x 512 byte sectors
%define INTERRUPT_VECTORS ( SECTOR_BUFFER - 0x0400 ) ; the IDT register points to these interrupt
vectors
%define VESA_BUFFER ( INTERRUPT_VECTORS - 0x0400 ) ; for the VESA mode information
%define DAP_BUFFER ( VESA_BUFFER - 0x0020 ) ; 0x1BE0 for the Int 0x13 Disk Address Packet
(DAP)
%define DISK_INFO ( DAP_BUFFER - 0x0020 ) ; for the Int 0x13 AH=08h get info
%define IDT_AND_PIC_SETTINGS ( DISK_INFO - 0x0040 ) ; bytes 0x00 - 0x05 SIDT value, 0x06 PIC1 IMR
, 0x07 PIC2 IMR values saved at startup
%define V_REGS ( IDT_AND_PIC_SETTINGS - 0x0020 ) ; test only - registers before and after thunk
call
%define MD5_OUTPUT_BUFFER ( V_REGS - 0x0020 ) ; the MD5 hash result

```

```

%define TRASH_BUFFER      ( ( 508 * 0x0400 ) + 0x10000 ) ; Block 508, saves words deleted while editing

%define PIC_BIOS_IDT_SETTINGS ( IDT_AND_PIC_SETTINGS ) ; bytes 0x00 - 0x05 SIDT value, 0x06 PIC1 IMR ,
0x07 PIC2 IMR values saved at startup
%define PIC_BIOS_IMR_SETTINGS ( IDT_AND_PIC_SETTINGS + 6 ) ; bytes 0x00 - 0x05 SIDT value, 0x06 PIC1 IMR
, 0x07 PIC2 IMR

%define PIC_NEW_IDT_SETTINGS ( IDT_AND_PIC_SETTINGS + 0x10 ) ; bytes 0x00 - 0x05 SIDT value, 0x08 new
PIC1 IMR , 0x09 new PIC2 IMR
%define PIC_NEW_IMR_SETTINGS ( IDT_AND_PIC_SETTINGS + 0x16 ) ; bytes 0x00 - 0x05 SIDT value, 0x08 new
PIC1 IMR , 0x09 new PIC2 IMR

%define IDT_AND_PIC_SETTINGS_PAD ( IDT_AND_PIC_SETTINGS + 0x20 )

%define vesa_BytesPerScanLine ( VESA_BUFFER + 0x0E ) ; screen width ( number of horizontal pixels )
%define vesa_XResolution      ( VESA_BUFFER + 0x12 ) ; screen width ( number of horizontal pixels )
%define vesa_YResolution      ( VESA_BUFFER + 0x14 ) ; screen height ( number of vertical pixels )
%define vesa_BitsPerPixel     ( VESA_BUFFER + 0x19 ) ; bits per pixel
%define vesa_SavedMode         ( VESA_BUFFER + 0x1E ) ; "Reserved" - we save the VESA mode here
%define vesa_PhysBasePtr       ( VESA_BUFFER + 0x28 ) ; address of linear frame buffer

%define BOOTOFFSET          0x7C00

%assign RELOC_BIT 16 ; the relocation address must be a power of 2
%assign RELOCATED 1 << RELOC_BIT ; 0x10000

; *****
; Data and Return stack allocation, four pairs of data and return stacks
; Note : the return stack must be in the lowest 64K byte segment, for the BIOS calls to work
; *****
%define DATA_STACK_SIZE_0 $0400 ;
%define DATA_STACK_SIZE_1 $0500 ; must be > $400 for colorForth "Life" program to work
%define DATA_STACK_SIZE_2 $0100 ;
%define DATA_STACK_SIZE_3 $0100 ;
%define DATA_STACK_SIZE_GAP $0100 ; leave space under the last data stack to check for underflow

%define RETURN_STACK_SIZE $0100 ;

; return stacks
%define RETURN_STACK_0 ( $7800 ) ; top of stack memory area
%define RETURN_STACK_1 ( RETURN_STACK_0 - RETURN_STACK_SIZE )
%define RETURN_STACK_2 ( RETURN_STACK_1 - RETURN_STACK_SIZE )
%define RETURN_STACK_3 ( RETURN_STACK_2 - RETURN_STACK_SIZE )

; data stacks
%define DATA_STACK_0 ( RETURN_STACK_3 - RETURN_STACK_SIZE )
%define DATA_STACK_1 ( DATA_STACK_0 - DATA_STACK_SIZE_0 ) ; BIG data stack for the show task
%define DATA_STACK_2 ( DATA_STACK_1 - DATA_STACK_SIZE_1 )
%define DATA_STACK_3 ( DATA_STACK_2 - DATA_STACK_SIZE_2 )
%define STACK_MEMORY_START ( DATA_STACK_3 - DATA_STACK_SIZE_3 - DATA_STACK_SIZE_GAP )

; four pairs of stacks, one for each task
%define TOTAL_STACK_SIZE ( RETURN_STACK_0 - STACK_MEMORY_START )

%define STACK_ANALYSIS_BUFFER ( STACK_MEMORY_START - 0x200 )

; *****
; *****

%define _TOS_ eax
%define _TOS_x_ ax
%define _TOS_l_ al

%define _SCRATCH_ ebx
%define _SCRATCH_x_ bx
%define _SCRATCH_l_ bl

%define _MOV_TOS_LIT_ (0xB8) ; the opcode for mov eax, 32_bit_literal (in next 32 bit cell)

%macro _DUP_ 0 ; Top Of Stack is in the _TOS_ register

```

```

        sub esi, byte 0x04          ; pre-decrement the stack pointer
        mov [ esi ], _TOS_          ; copy the Top Of Stack ( TOS ) register to Second On Stack ( on the real
stack )
%endmacro

%macro _SWAP_ 0
        xchg _TOS_, [ esi ]
%endmacro

%macro _OVER_ 0
        sub esi, byte 0x04          ; pre-decrement the stack pointer
        mov [ esi ], _TOS_          ; copy the Top Of Stack ( TOS ) register to Second On Stack ( on the real
stack )
        mov _TOS_, [ esi + 4 ]
%endmacro

%macro _DROP_ 0
        lodsd ; loads a 32 bit dword from [ds:esi] into  eax  then increments  esi  by 4
%endmacro
; Note : stosd ; stores  eax  into the location pointed to by  edi  then increments  edi  by 4
; Note also : eax is used as  _TOS_  ( Top Of Stack )

#define START_OF_RAM    0x00468000
#define ForthNames      START_OF_RAM          ; copied to RAM here from ROM ( i.e. boot program )
version
#define ForthJumpTable  ( ForthNames + 0x2800 ) ; copied to RAM here from ROM ( i.e. boot program )
version
#define MacroNames      ( ForthJumpTable + 0x2800 ) ; copied to RAM here from ROM ( i.e. boot program )
version
#define MacroJumpTable  ( MacroNames + 0x2800 ) ; copied to RAM here from ROM ( i.e. boot program )
version

#define H0              ( MacroJumpTable + 0x2800 ) ; initial value of the dictionary pointer

#define SECTOR  512      ; bytes per floppy sector
#define HEADS   2        ; heads on 1.44M floppy drive
#define SECTORS 18       ; floppy sectors per track
#define CYLINDER (SECTOR * SECTORS * HEADS)
#define CELL 4          ; bytes per cell
#define DEBUGGER 0xe1    ; port to hardware debugger?

; int 0x13 Disk Address Packet (DAP) pointed to by  si  :
#define o_Int13_DAP_size      ( 0x00 ) ; 2  0x0010
#define o_Int13_DAP_num_sectors ( 0x02 ) ; 2  0x0001
#define o_Int13_DAP_address   ( 0x04 ) ; 2  0x2000
#define o_Int13_DAP_segment   ( 0x06 ) ; 2  0x0000
#define o_Int13_DAP_LBA_64_lo ( 0x08 ) ; 4  0x00000028
#define o_Int13_DAP_LBA_64_hi ( 0x0C ) ; 4  0x00000000
; extended DAP values
#define o_Int13_DAP_readwrite   ( 0x10 ) ; 2  0x0000
#define o_Int13_DAP_saved_DX    ( 0x12 ) ; 2  0x0000
#define o_Int13_DAP_returned_AX ( 0x14 ) ; 2  0xHH00 see AH Return Code below
#define o_Int13_DAP_returned_carry_flag ( 0x16 ) ; 2  0x0000
#define o_Int13_DAP_saved_CHS_CX ( 0x18 ) ; 2  0x0000
#define o_Int13_DAP_saved_CHS_DX ( 0x1A ) ; 2  0x0000

%macro LOAD_RELATIVE_ADDRESS 1
        mov _TOS_, ( ( ( %1 - $$ ) + RELOCATED ) )
%endmacro

; emit the given following character
%macro EMIT_IMM 1
;        push esi
        _DUP_
        mov _TOS_, %1
        call emit_
;        pop esi
%endmacro

; *****

```

```

; Registers used
; *****
; _TOS_ is the top stack item ( eax --> ebx )
; esp the call ... ret return stack pointer
; edi dictionary pointer ( H --> : HERE ( -- a ) H @ ; )
; esi is the stack pointer, also needed by lods and movs
; e.g. lodsd loads a 32 bit dword from [ds:esi] into _TOS_, increments esi by 4
; ebx scratch register
; ecx counter and scratch register
; edx run-time pointer (?), "a register" used by a! , otherwise scratch register
; ebp variable pointer register
; "ds" = selector 0x10 ==> 0x0000:0000
; "es" = selector 0x10 ==> 0x0000:0000
; "ss" = selector 0x10 ==> 0x0000:0000

; colours RGB in 16 bits
colour_background equ 0x0000
colour_yellow     equ 0xFFE0
colour_black      equ 0x0000
colour_red        equ 0xF800
colour_green      equ 0x0600
colour_cyan       equ 0x07FF
colour_white      equ 0xFFFF
colour_light_blue equ 0x841F
colour_silver     equ 0xC618
colour_magenta    equ 0xF81F
colour_magentaData equ 0xD010
colour_blue       equ 0x001F
colour_orange     equ 0xE200
colour_dark_yellow equ 0xFFE0
colour_dark_green equ 0x07C0
colour_PacMan     equ 0xE200
colour_blockNumber equ 0xE200

[BITS 16]                                ; Real Mode code (16 bit)

org RELOCATED

start:
codeStart:
    jmp main_16bit    ; 0x03 bytes | EB 58 90 00 Jump to boot code
    times 3 - ($ - $$) nop    ; fill with 1 or 0 no-ops to address 3
; BIOS boot parameter table = 0x25 bytes
    db 'cf2022 0'          ; 03 Eight byte OEM name
    dw 0x0200              ; 11 Number of Bytes Per Sector
    dw 0x08                ; 13 Number of Sectors Per Cluster
    dw 0x05E0              ; 14 Number of Reserved Sectors until the FAT
    db 0x02                ; 16 Number of Copies of FAT : always = 2
    dw 0x0000              ; 17 Maximum number of Root Directory Entries
    dw 0x0000              ; 19 Not used for FAT32
    db 0xF8                ; 21 Media type F0 = 1.44M 3.5 inch floppy disk, F8 = hard disk changes 2022 Mar14
    dw 0x0000              ; 22 Sectors Per FAT for FAT12 and FAT16 - not used for FAT32
    dw 0x003F              ; 24 Sectors per Track
    dw 0x00FF              ; 26 Number of heads
    dd 0x00000038          ; 28 Hidden sectors preceding the partition that contains this FAT volume
    dd 0x007477C8          ; 32
    dd 0x00001D10          ; 36 Sectors Per FAT for FAT32
    dw 0x0000              ; 40
    dw 0x0000              ; 42
    dd 0x00000002          ; 44 Start of all directories, including root.
    dw 0x0001              ; 48
    dw 0x0006              ; 50 Offset in sectors from this sector to the backup BPB sector
; times 12 db 0            ; 0x0C bytes | 00 00 00 00 00 00 00 00 00 00 00 52
; db 0x00                  ; 64
; db 0x00                  ; 65
; db 0x29                  ; 66 Extended Boot Signature
; dd 0x44444444            ; 67 serial number
; db 'colorForth '         ; 71 Eleven byte Volume Label
; db 'cFblocks'            ; 82 Eight byte File System name

```

```

; *****
; *****

align 8, nop    ; has to be aligned to 8 for GDT
    ; Note : we are NOT using null descriptor as GDT descriptor, see: http://wiki.osdev.org/GDT\_Tutorial
    ; "The null descriptor which is never referenced by the processor. Certain emulators, like Bochs, will
    ; complain about limit exceptions if you do not have one present.
    ; Some use this descriptor to store a pointer to the GDT itself (to use with the LGDT instruction).
    ; The null descriptor is 8 bytes wide and the pointer is 6 bytes wide so it might just be the perfect
    ; place for this."

gdt:                ; the GDT descriptor
    dw gdt_end - gdt - 1    ; GDT limit
    dw gdt0 + BOOTOFFSET    ; pointer to start of table, low 16 bits
    dw 0 , 0                ; the high bits of the longword pointer to gdt

gdt0:                ; null descriptor
    dw 0    ; 0,1 limit 15:0
    dw 0    ; 2,3 base 15:0
    db 0    ; 4 base 23:16
    db 0    ; 5 type
    db 0    ; 6 limit 19:16, flags
    db 0    ; 7 base 31:24
code32p_SELECTOR_0x08 equ $ - gdt0
; bytes 1 0 3 2 5 4 7 6
    dw 0xFFFF, 0x0000, 0x9A00, 0x00CF    ; 32-bit protected-mode code, limit 0xFFFF
data32p_SELECTOR_0x10 equ $ - gdt0
    dw 0xFFFF, 0x0000, 0x9200, 0x00CF    ; 32-bit protected-mode data, limit 0xFFFF
code16r_SELECTOR_0x18 equ $ - gdt0
    dw 0xFFFF, 0x0000, 0x9A00, 0x0000    ; 16-bit real-mode code, limit 0xFFFF
data16r_SELECTOR_0x20 equ $ - gdt0
    dw 0xFFFF, 0x0000, 0x9200, 0x0000    ; 16-bit real-mode data, limit 0xFFFF
gdt_end:

; *****
; *****

; align to 4 so we can access variables from high-level Forth
align 4, nop

data_area:    ; data area begins here

bootsector:    ; LBA of boot sector
    dd 0

; save disk information, cylinder, sector, head and drive from BIOS call
driveinfo_Drive_DX:    ; use low byte to store boot Drive into from BIOS DL
    dw 0

driveinfo_CX:    ; [7:6] [15:8][7] logical last index of cylinders = number_of - 1 (because index
starts with 0)
    ; [5:0][7] logical last index of sectors per track = number_of (because index starts
with 1)
    dw 0

; cylinders, sectors, heads of boot drive
; low word: high byte is head
; high word: cylinder and sector: C76543210 C985543210
driveinfo_Cylinder:
    db 0
driveinfo_Head:
    db 0
driveinfo_SectorsPertrack:
    dw 0

align 4, nop

destination:
    dd RELOCATED

```

```

dispPtr:
    dd 0x00000140

v_bytesPerLine:
    dd 0x00

v_scanCode:
    dd 0x00

align 4

; *****
; the main program called from initial 16 bit mode
; *****

main_16bit:

    cli                                ; clear interrupts
                                        ; turns out we don't need interrupts at all, even when using BIOS routines
                                        ; but we need to turn them off after disk calls because BIOS leaves them
on

    push si                            ; need to transfer SI to unused register BX later

; note: cannot touch DX or BP registers until we've checked for partition boot
; (SI could be used as well as BP but we use SI for relocation)

; see mbrboot.nasm

    pop bx                            ; Note : relocate the bootblock before we do anything else
                                        ; we cannot use the current stack after changing SS or SP
                                        ; ... because mbrboot.nasm places stack at 0x7c00, in SECTOR_BUFFER
                                        ; and we cannot use BP because its default segment is SS

    xor ax, ax
    mov ds, ax
    mov es, ax

    mov si, BOOTOFFSET
    mov di, SECTOR_BUFFER
    mov sp, di
    mov cx, 0x100
    rep movsw                        ; note that this instruction doesn't change AX , it moves DS:SI to ES:DI
and increments SI and DI

    mov ss, ax                        ; stack segment also zero
    mov ah, 0xb8                      ; video RAM
    mov gs, ax                        ; store in unused segment register

    lgdt [gdt - $$ + BOOTOFFSET]

    call SetupUnrealMode             ; gs and ss must be initialized before going to Unreal Mode

; *****
; Enable the A20 address line, otherwise all odd 1 MByte pages are disabled
; Using the "PS/2 Controller" or 8042 "Keyboard controller"
; *****
; from http://wiki.osdev.org/%228042%22\_PS/2\_Controller#Step\_1:\_Initialise\_USB\_Controllers
; Write a command to the on-board 8042 "Keyboard controller" port 0x64 :
; 0x20 Read "byte 0" from internal RAM Controller Configuration Byte
; 0x21 to 0x3F Read "byte N" from internal RAM (where 'N' is the command byte & 0x1F)
; 0x60 Write next byte to "byte 0" of internal RAM (Controller Configuration Byte)
; 0x61 to 0x7F Write next byte to "byte N" of internal RAM (where 'N' is the command byte & 0x1F)
; 0xA7 Disable second PS/2 port
; 0xA8 Enable second PS/2 port
; 0xA9 Test second PS/2 port
; 0x00 test passed
; 0x01 clock line stuck low
; 0x02 clock line stuck high
; 0x03 data line stuck low
; 0x04 data line stuck high
; 0xAA Test PS/2 Controller

```



```

; 0x55 test passed
; 0xFC test failed
; 0xAB Test first PS/2 port
; 0x00 test passed
; 0x01 clock line stuck low
; 0x02 clock line stuck high
; 0x03 data line stuck low
; 0x04 data line stuck high
; 0xAC Diagnostic dump (read all bytes of internal RAM) Unknown
; 0xAD Disable first PS/2 port None
; 0xAE Enable first PS/2 port None
; 0xC0 Read controller input port Unknown (none of these bits have a standard/defined purpose)
; 0xC1 Copy bits 0 to 3 of input port to status bits 4 to 7 None
; 0xC2 Copy bits 4 to 7 of input port to status bits 4 to 7 None
; 0xD0 Read Controller Output Port Controller Output Port (see below)
; 0xD1 Write next byte to Keyboard Controller Output Port Note: Check if output buffer is empty
first
; 0xD2 Write next byte to first PS/2 port output buffer
; 0xD3 Write next byte to second PS/2 port output buffer
; 0xD4 Write next byte to second PS/2 port input buffer
; 0xFF Pulse output line low for 6 ms.
; Bits 0 to 3 are used as a mask (0 = pulse line, 1 = do not pulse line) and correspond to 4
different output lines.
; Bit 0 is the "reset" line, active low.
mov al, 0xD1 ; 0xD1 = Write next byte to Keyboard Controller Output Port
out 0x64, al ; On-board controller Command Write
.back:
in al, 0x64
and al, 0x02
jnz .back
mov al, 0x4B
out 0x60, al

; *****
; Get disk drive parameters from the BIOS
; *****

mov di, (data_area - $$ + BOOTOFFSET) ; setup the data index pointer
xor eax, eax
bts eax, 16 ; in case NOT booted from partition: sector 1, head 0, cylinder 0
or dh, dh ; booted from partition?
jz .forward3
mov eax, [bx + 8] ; SI (now BX) contains pointer to partition record
mov [byte di + (bootsector - data_area)], eax ; offset 8 was LBA of first absolute sector
mov eax, [bx] ; CHS of first sector in partition
.forward3:
mov al, dl ; bootdrive into AL
mov [word di + (driveinfo_Drive_DX - data_area)], eax ; save the Drive info from BIOS
mov ah, 8 ; get drive parameters
push es ; this operation messes with ES
push di ; and DI
mov di, DISK_INFO ; point di at the table returned by this software interrupt
int 0x13
jc $ ; stop here on error

call ReSetupUnrealMode
pop di
pop es

; *****
; load the bootdisk into both low and high RAM
; *****

mov [byte di + (driveinfo_Cylinder - data_area)], dx ; heads in high byte
and cl, 0x3F ; we don't care about two high bits of cylinder count
mov [byte di + (driveinfo_SectorsPertrack - data_area)], cx ; cylinders and sectors/track
mov dx, [byte di + (driveinfo_Drive_DX - data_area)] ; restore dl Drive value from BIOS, dh
= 0
; mov dl, 0x00 ; try this 2022 Mar 14
mov cx, [di + (driveinfo_CX - data_area)] ; restore cl value, ch = 0

```

```

    mov si, SECTORS_TO_LOAD

    mov bx, SECTOR_BUFFER          ; relocate the sector we are running from
    call relocate

    mov bx, BOOTOFFSET             ; we will fix this below by adding 0x200
                                   ; remember the sector is 1-based, head and cylinder both 0-based

.nextsector:
    inc cl
    dec si
    jz setVideoMode      ; success, so setup the video now...

.bootload:
    mov ax, 0x201           ; read 1 sector
    add bh, 0x02            ; into next available slot in RAM
    jnz .forward
    sub bh, 0x02            ; at 0x10000 we go back to 0xfe00

.forward:
    int 0x13
    call ReSetupUnrealMode
    jc $                    ; stop here on error
    call relocate
    mov al, cl
    and al, 0x3F            ; low 6 bits
    cmp al, [ byte di + ( driveinfo_SectorsPertrack - data_area) ]
    jnz .nextsector
    inc dh                  ; next head
    cmp dh, [ byte di + ( driveinfo_Head - data_area) ]
    jna .forward2           ; not JNZ, the head index is 1 less than head count
    xor dh, dh
    inc ch                  ; next cylinder
    jnz .forward2
    add cl, 0x40            ; bit 8 of cylinder count

.forward2:
    and cl, 0xC0            ; clear sector count, low 6 bits of cl
    jmp short .nextsector

; *****
; *****
; Start here after loading the program
; *****
; *****

; From : VESA BIOS EXTENSION (VBE) Core Functions Standard Version: 3.0 Date: September 16, 1998
; Mandatory information for all VBE revisions
; dw ModeAttributes          ; 0x00 mode attributes
; db WinAAttributes          ; 0x02 window A attributes
; db WinBAttributes          ; 0x03 window B attributes
; dw WinGranularity          ; 0x04 window granularity
; dw WinSize                 ; 0x06 window size
; dw WinASegment             ; 0x08 window A start segment
; dw WinBSegment             ; 0x0A window B start segment
; dd WinFuncPtr              ; 0x0C real mode pointer to window function
; dw BytesPerScanLine        ; 0x10 bytes per scan line          <-----
; Mandatory information for VBE 1.2 and above
; dw XResolution              ; 0x12 horizontal resolution in pixels <----- scrnw
; dw YResolution              ; 0x14 vertical resolution in pixels  <----- scrnh
; db XCharSize                ; 0x16 character cell width in pixels
; db YCharSize                ; 0x17 character cell height in pixels
; db NumberOfPlanes           ; 0x18 number of memory planes
; db BitsPerPixel             ; 0x19 bits per pixel              <----- bpp
; db NumberOfBanks            ; 0x1A number of banks
; db MemoryModel              ; 0x1B memory model type
; db BankSize                 ; 0x1C bank size in KB
; db NumberOfImagePages       ; 0x1D number of images
; db Reserved                 ; 0x1E reserved for page function    <----- mode (we copy it
here)
; Direct Color fields (required for direct/6 and YUV/7 memory models)
; db RedMaskSize              ; 0x1F size of direct color red mask in bits

```

```

; db RedFieldPosition      ; 0x20 bit position of lsb of red mask
; db GreenMaskSize         ; 0x21 size of direct color green mask in bits
; db GreenFieldPosition    ; 0x22 bit position of lsb of green mask
; db BlueMaskSize          ; 0x23 size of direct color blue mask in bits
; db BlueFieldPosition     ; 0x24 bit position of lsb of blue mask
; db RsvdMaskSize          ; 0x25 size of direct color reserved mask in bits
; db RsvdFieldPosition     ; 0x26 bit position of lsb of reserved mask
; db DirectColorModeInfo   ; 0x27 direct color mode attributes
; Mandatory information for VBE 2.0 and above
; dd PhysBasePtr           ; 0x28 physical address for flat memory frame buffer <----- vframe
; dd Reserved              ; 0x2C Reserved - always set to 0
; dw Reserved              ; 0x30 Reserved - always set to 0
; Mandatory information for VBE 3.0 and above
; dw LinBytesPerScanLine   ; 0x32 bytes per scan line for linear modes
; db BnkNumberOfImagePages ; 0x34 number of images for banked modes
; db LinNumberOfImagePages ; 0x35 number of images for linear modes
; db LinRedMaskSize        ; 0x36 size of direct color red mask (linear modes)
; db LinRedFieldPosition   ; 0x37 bit position of lsb of red mask (linear modes)
; db LinGreenMaskSize      ; 0x38 size of direct color green mask (linear modes)
; db LinGreenFieldPosition ; 0x39 bit position of lsb of green mask (linear modes)
; db LinBlueMaskSize       ; 0x3A size of direct color blue mask (linear modes)
; db LinBlueFieldPosition  ; 0x3B bit position of lsb of blue mask (linear modes)
; db LinRsvdMaskSize       ; 0x3C size of direct color reserved mask (linear modes)
; db LinRsvdFieldPosition  ; 0x3D bit position of lsb of reserved mask (linear modes)
; dd MaxPixelClock         ; 0x3E maximum pixel clock (in Hz) for graphics mode
; times 189 db 0           ; 0x42 remainder of ModeInfoBlock
; End                      ; 0xFF

```

```

scanVESA:  ; ( w+h+b -- ) in ax
            mov bx, ax
            push di
            mov cx, ( 0x4117 - 1 ) ; save di
                                           ; start scanning from the expected VESA mode 0x4117 ( the -1 is
because of the inc cx below )
.back:
            inc cl                      ; increment just the bottom byte, we test 0x41xx
            cmp cl, 0x16                ; scanned from 0x4117 to 0x4116, not found, so show error
            jz .failure
            mov di, VESA_BUFFER        ; buffer for the VESA mode information block
            mov ax, 0x4F01              ; INT 0x10, AX=0x4F01, CX=mode Get Mode Info
            int 0x10
            cmp al, 0x4F                ; success code = 0x4F
            jne .back                  ; try the next VESA mode
            mov ax, [di + 0x12]          ; width
            add ax, [di + 0x14]          ; height
            add al, [di + 0x19]          ; bits per pixel
;         adc ah, 0                    ; should not be necessary for the expected result, 0x400+0x300+0x10
            cmp ax, bx                  ; width + height + bits per pixel
            je .success
            jne .back                  ; try the next VESA mode
.failure:
            pop di                      ; restore di
            mov ax, 0                   ; return flag false
            add ax, 0                   ; set the zero flag
            ret
.success:
            mov [ di + ( vesa_SavedMode - VESA_BUFFER ) ], cx ; save the VESA mode in the VESA_BUFFER at offset
0x1E "Reserved"
            mov ax, 1                   ; return flag true
            add ax, 0                   ; set the zero flag
            pop di                      ; restore di
            ret

```

```

setVESA:    ; we found a valid VESA mode

```

```

            push ds                    ; clear all flags including Interrupt using DS, known to be zero
            popf                      ; this is necessary to clear T flag also, end register display

            call greet                ; show greeting message

            mov bx, cx

```

```

mov ax, 0x4F02 ; INT 0x10, AX=0x4F02, BX=mode, ES:DI=CRTCInfoBlock Set Video Mode
int 0x10

jmp main_32bit

setVideoMode:
%if ( FORCE_800x600_VESA == 0 ) ; test the 800x600 mode in bochs, which supports 1024x768
mov ax, ( 1024 + 768 + BITS_PER_PIXEL ) ; try the highest resolution first
call scanVESA ; if VESA mode is found, jump to setVESA
jnz setVESA ; success - we found the requested VESA mode
%endif
mov ax, ( 800 + 600 + BITS_PER_PIXEL ) ; then try a lower resolution
call scanVESA ; if VESA mode is found, jump to setVESA
jnz setVESA ; success - we found the requested VESA mode

; mov ax, 640 + 480 + BITS_PER_PIXEL ; then try an even lower resolution
; call scanVESA ; if VESA mode is found, jump to setVESA
; jnz setVESA ; success - we found the requested VESA mode
jmp showVESAerror ; we have tried all VESA modes without success, so report an error

; *****
; *****

relocate: ; copy 512 bytes from [bx] to FS:[destination]
pusha
mov cx, 0x200 / 2
mov si, bx
mov ebx, [ byte di + ( destination - data_area) ]
.back:
lodsw ; load the 16 bit value pointed to by SI into ax
mov [fs:ebx], ax ; Note : the fs: uses the 32 bit FS value setup in Unreal Mode to move the data
outside of the 1 Mbyte Real Mode address range
add ebx, byte +2
loop .back

mov [ byte di + ( destination - data_area) ], ebx
popa
ret

; not used because it is very slow :
; now set up for trap displaying registers on screen during bootup
; push cs
; push showstate - $$ + BOOTOFFSET
; pop dword [word +4]

; *****
; *****
; 1. MasterBoot Record - MBR at Sector 0 (decimal) MBR
; Partition at offset 1BE
; BootSignature 0
; Start Head|Sector|Cylinder 1 1 0
; Partition Type B DOS 7.1+
; End Head|Sector|Cylinder FE 3F 3E5
; BPBsectorNumber 00 \ was 3F
; Size of partition (decimal) 16035777 sectors, 8210317824 bytes, 8017889 Ki bytes, 7830 Mi bytes,
8 Gi bytes
; Partition at offset 1CE
; BootSignature 0
; Start Head|Sector|Cylinder 0 0 0
; Partition Type 0 Empty partition
; End Head|Sector|Cylinder 0 0 0
; BPBsectorNumber 0
; Size of partition (decimal) 0 sectors, 0 bytes, 0 Ki bytes, 0 Mi bytes,

; pretend to be a Master Boot Record so that the BIOS will load us
times ( 0x000001BE - ( $ - $$ ) ) db 0x77
db 0x80, 0x01, 0x01, 0x00, 0x0B, 0xFE, 0xFF, 0xE5, 0x00, 0x00, 0x00, 0x00, 0xC1, 0xAF, 0xF4, 0x00 ;
0x1BE DOS partition 0 working on PC
db 00, 00, 00, 00, 00, 00, 00, 00 ; 0x1CE first 8 bytes of empty partition 1

```

```

SetupUnrealMode:
    ; set the FS segment in "unreal" mode, must be done before the Trap Flag is set in EFLAGS register
    mov eax, cr0
    or al, 1      ; set the "protected mode enable" bit => "unreal mode"
    mov cr0, eax
    push word data32p_SELECTOR_0x10 ; set the FS segment
    pop fs
    dec al        ; clear the "protected mode enable" bit
    mov cr0, eax
    push ds        ; now set FS to 0
    pop fs

```

```

ReSetupUnrealMode:
    push cs        ; for iret
    pushf          ; for iret
    pusha
    mov bp, sp
    mov ax, [bp + 16] ; get flags
;   or ah, 0x01    ; set Trap Flag, bit 8 in the EFLAGS register ; debug only - very
slow!
    and ah, ~0x02   ; reset interrupt flag
    xchg ax, [bp + 20] ; swap flags with return address
    mov [bp + 16], ax ; return address at top of stack after popa
    popa
    iret

```

```

; *****
; *****

```

```

times 512 - 2 - ($ - $$) nop      ; fill with no-ops to 55AA at end of boot sector
    db 0x55, 0xAA ; boot sector terminating bytes

```

```

; *****
; End of Boot Sector
; *****

```

```

; *****
; Show the user a null terminated string - writes directly into video RAM
; *****

```

```

displayString:

```

```

    ; restore the pointer to screen memory into di
    mov di, (data_area - $$ + BOOTOFFSET)
    mov ax, [di + (dispPtr - data_area)]
    mov di, ax

```

```

    push es        ; save es
    mov ax, 0xb800 ; video RAM segment
    mov es, ax

```

```

backhere2:
    lodsb          ; loads a byte from [ds:si] into al, then increments si
    cmp al, 0
    jz forward1    ; If al = 0 then leave the loop
    mov ah, 0x0D    ; text colour, magenta on black background
    stosw          ; stores ax into [es:di] then increments di
    jmp backhere2

```

```

forward1:
    ; save the pointer to screen memory from di
    mov ax, di
    mov di, (data_area - $$ + BOOTOFFSET)
    mov [di + (dispPtr - data_area)], ax
    pop es        ; restore es
    ret

```

```

; display a string then Wait for a key press
displayStringW:

```

```

    pusha

```

```

    call displayString

    xor ax, ax      ; wait for and get a key press ( AX = 0 )
    int 0x16        ; BIOS interrupt Read a Key From the Keyboard
    popa
    ret

; msg_greeting2:
;   db ' Press any key : ' , 0x00

msg_VESAerror:
    db 'No valid VESA mode found! ' , 0x02, 0x00
;   db ' No VESA mode ' , 0x02, 0x00

[BITS 16]                                ; Real Mode code (16 bit)

showVESAerror:
    call greet
    push si
    mov word [ di + ( dispPtr - data_area) ] , 0x000001E0 ; line 3 0x50 x 2 x 3 = 0x1E0
    mov si, ( msg_VESAerror - $$ + BOOTOFFSET ) ; string to display
    call displayStringW
    pop si
    ret

greet:      ; jump here to show 16 bit version text
    push si
    mov word [ di + ( dispPtr - data_area) ] , 0x00000140 ; line 2 0x50 x 2 x 2 = 0x140
    mov si, ( version - $$ + BOOTOFFSET ) ; string to display
    call displayString
;   mov si, ( msg_greeting2 - $$ + BOOTOFFSET ) ; string to display
;   call displayStringW
    pop si
    ret

; *****
; the main program in 32 bit ( protected ) mode
; *****

main_32bit:

    call setProtectedModeAPI      ; called from 16 bit code, returns in 32 bit code

[BITS 32]                                ; Protected Mode code (32 bit) - assemble for 32 bit mode from now on

    mov esp, RETURN_STACK_0        ; setup the return stack pointer
    mov esi, ( DATA_STACK_0 + 4 ) ; setup our data stack pointer

    call save_BIOS_idt_and_pic      ; to be restored later, when making BIOS calls
    call init_default_PIC_IMRs      ; set the default values and copy the BIOS Interrupt Vectors to our
new table
    _DUP_
    mov _TOS_, INTERRUPT_VECTORS
    call lidt_                      ; Load the new Interrupt Descriptor Table

    jmp dword warm

; *****
; calculate Cylinder, Head and Sector from zero-based sector number
; see http://teaching.idallen.com/dat2343/00f/calculating\_cylinder.htm
; Note : uses pushad to copy registers onto the ESP stack, stores the
; calculated values onto the stack at the correct offsets, then restores the
; stack back to the registers.
; *****

sector_chs: ; ( sector -- eax ) calculate CHS from a sector number in eax,
; returns with DX = HHDD, CX = CCSS where HH=head, DD=drive, CC=cylinder, SS=sector
; Note that the input sector number is zero based, and that the high 16 bits of EAX must be 0
    pushad ; Pushes all general purpose registers onto the stack in the following order:

```

```

; EAX, ECX, EDX, EBX, ESP, EBP, ESI, EDI. The value of ESP is the value before the actual push of
ESP
; 7 6 5 4 3 2 1 0 offset in cells from ESP
mov ebp, esp ; copy the original ESP stack pointer to EBP so we can access items on the stack
easily

```

```

; save the register values in the DAP buffer for use later, via ESI
mov esi, DAP_BUFFER

add eax, [ bootsector - $$ + BOOTOFFSET]
push eax ; save it while we calculate heads*sectors-per-track
mov al, [ driveinfo_Head - $$ + BOOTOFFSET] ; index of highest-numbered head
inc al ; 1-base the number to make count of heads
mul byte [ driveinfo_SectorsPertrack - $$ + BOOTOFFSET] ; sectors per track
mov ebx, eax
pop eax
xor edx, edx ; clear high 32 bits
div ebx ; leaves cylinder number in eax, remainder in edx
mov ecx, eax ; store cylinder number in another register
mov eax, edx ; get remainder into AX
mov bl, [ driveinfo_SectorsPertrack - $$ + BOOTOFFSET] ; number of sectors per track
div bl ; head number into AX, remainder into DX
mov bl, al ; result must be one byte, so store it in BL
rol ecx, 8 ; high 2 bits of cylinder number into high 2 bits of CL
shl cl, 6 ; makes room for sector number
or cl, ah ; merge cylinder number with sector number
inc cl ; one-base sector number
mov [ ebp + ( 6 * 4 ) ], ecx ; store the result in ECX position on esp stack
mov word [ esi + o_Int13_DAP_saved_CHS_CX ], cx ; also save the calculated CX value
mov cx, [ driveinfo_Drive_DX - $$ + BOOTOFFSET] ; drive number in low 8 bits
mov ch, bl ; place head number in high bits
; mov cl, 0x80
mov [ ebp + ( 5 * 4 ) ], ecx ; store the result in EDX position on esp stack
mov word [ esi + o_Int13_DAP_saved_CHS_DX ], cx ; also save the calculated DX value
popad ; restore registers from esp stack
ret

```

```

; *****
; enter Protected Mode (32 bit) and Real Mode (16 bit)
; from http://ringzero.free.fr/os/protected%20mode/Pm/PM1.ASM
; *****

```

[BITS 16] ; Real Mode code (16 bit)

```

enterProtectedMode: ; must come from a 'call' , can not be inlined
    pop ax
    push code32p_SELECTOR_0x08
    push ax
    retf

```

```

setProtectedModeAPI: ; set protected mode from 'Real' mode. Called from 16 bit code,
returns to 32 bit code
    pushad ; save all registers as doublewords
    mov eax, cr0
    or al, 1
    mov cr0, eax ; set the Protected Mode bit in the Control Register
    xor eax, eax ; clear high bits of eax
    call enterProtectedMode

```

[BITS 32] ; Protected Mode code (32 bit)

```

    mov eax, data32p_SELECTOR_0x10 ; Protected Mode data segment
    mov es, ax
    mov ds, ax
    mov ss, ax ; this makes stack segment 32 bits
    popad
    o16 ret

```

```

enter16bitProtectedMode: ; 32 bit code. Must come from a 'call' , can not be inlined
    pop eax ; return address

```

```

    push dword code16r_SELECTOR_0x18    ; select 16-bit Protected Mode AKA 'Real' Mode
    push eax
    retf

setRealModeAPI:                        ; set 'Real' mode from protected mode.
                                        ; Called from 32 bit code, returns to 16 bit code
                                        ; assumed that protected-mode stack is based at 0
                                        ; and that bits 16 through 19 will not change during time in realmode
    pushad                            ; save 32-bit values of registers
    mov ecx, esp                      ; do all possible 32-bit ops before going to 16 bits
    mov edx, cr0
    call enter16bitProtectedMode

[BITS 16]                             ; Real Mode code (16 bit)

    mov ax, data16r_SELECTOR_0x20
    mov ds, ax
    mov es, ax
    mov ss, ax                        ; here the stack becomes 16 bits based at 0, and SP used not ESP
                                        ; *** consider stack to be invalid from here until we reach real mode
***
    xor cx, cx                        ; clear low 16 bits
    shr ecx, 4                        ; move high 4 bits into cl
    dec dl                            ; leave protected mode, only works if we KNOW bit 0 is set
    mov cr0, edx
    call enterRealMode
    xor ax, ax
    mov ds, ax
    mov es, ax
    mov ss, cx
    ; note we don't need to set SP to 8xxx if ESP is b8xxx, since
    ; the b000 is now in SS, and the b of b8xxx is ignored in real mode
    popad
    o32 ret

enterRealMode:                        ; 16 bit code. Must come from a 'call', can not be inlined
    pop ax
    push fs                           ; real-mode code segment
    push ax
    retf

[BITS 32]                             ; Protected Mode code (32 bit)

; *****
; *****

%include "JCreawrite.nasm"
; JCreawrite.nasm 2012 Oct 23  read and write the disk using 16 bit BIOS calls
; BIOS read and write routines for colorForth

[BITS 32]                             ; Protected Mode code (32 bit)

bios_read: ; ( a c -- a' c' ) \ read cylinder c into address a , leave next address and cylinder
                                        ; c is cylinder, we will use 1.44Mb floppy's idea of cylinder
regardless
                                        ; a is byte address
                                        ; leave updated c and a on stack as c' and a'
                                        ; a cylinder is 36 tracks of 512 bytes each, 0x4800 bytes, 0x1200
cells (words)

    cli                              ; disable interrupts
    pushad                           ; push all registers ( except esp ) and flags onto the stack
    mov ebp, esp                     ; copy of stack pointer for use below ( * ), points to registers
copied by pushad , above

    mov ecx, HEADS * SECTORS         ; sectors per track (both heads)
    mul cl                           ; sector number goes into AX
                                        ; note that resultant sector number is zero-based going into
sector_chs!

                                        ; set up loop to read one floppy cylinder's worth

```



```

    push eax                                ; absolute sector number to start
.back:
    push ecx
    call sector_chs                        ; convert to Cylinder-Head-Sector in CX-DX
    call .readsector

    mov ebx, [ ebp + ( 1 * 4 ) ]           ; ( * ) get ESI stored on stack, via stack pointer saved in ebp
    mov edi, [ebx]                        ; destination index address for movsd
    mov ecx, ( 512 >> 2 )                 ; number of 32-bit words to move, 512 bytes
    mov esi, SECTOR_BUFFER                ; source index for movsd
    rep movsd                             ; copy ecx 32 bit words from ds:esi to es:edi
    mov [ebx], edi
    pop ecx
    pop eax
    inc eax
    push eax
    loop .back
    pop eax
    inc dword [ebp + 7 * 4]                ; for updated cylinder number after return
    popad
    ret

.readsector:                               ; no need to save registers because we take care of them in calling
routine
    call setRealModeAPI
[BITS 16]                                  ; Real Mode code (16 bit)
    mov bx, SECTOR_BUFFER
    mov ax, 0x0201                         ; read 1 sector
    int 0x13
    cli                                    ; BIOS might have left interrupts enabled
    call setProtectedModeAPI               ; called from 16 bit code, returns to 32 bit code
[BITS 32]                                  ; Protected Mode code (32 bit)
    ret

bios_write:    ; ( a c -- a' c' ) \ write cylinder c from address a , leave next address and cylinder
    cli                                    ; disable interrupts
    pushad
    mov ebp, esp

    mov ecx, HEADS * SECTORS                ; eax contains cylinder to start, the 'c' parameter
    mul cl                                  ; sectors per track (both heads)
                                           ; absolute sector number goes into AX

    mov ebx, [ebp + ( 1 * 4 ) ]             ; stored ESI on stack
    mov esi, [ebx]                         ; word address, 'a' parameter
;    shl esi, 2                             ; change word address into byte address
                                           ; set up loop to write one floppy cylinder's worth
    push eax                                ; absolute sector number to start

.back:
    push ecx                                ; load sector data into buffer
                                           ; DO NOT take advantage of knowing ECX only has byte value
                                           ; number of 32-bit words to move
    mov ecx, 128 ; ( 512 >> 2 )
    mov edi, SECTOR_BUFFER
    rep movsd                             ; copy ecx 32 bit words from ds:esi to es:edi
    call sector_chs                        ; convert to Cylinder-Head-Sector in CX-DX
    call .writesector
    pop ecx
    pop eax
    inc eax
    push eax
    loop .back
    pop eax
    inc dword [ ebp + ( 7 * 4 ) ]           ; for updated cylinder after return (EAX)
    mov ebx, [ ebp + ( 1 * 4 ) ]           ; stored ESI on stack
    mov [ebx], esi                         ; updated address
    popad
    ret

```

```

.writesector:                ; no need to save registers because we take care of them in calling
routine
    call setRealModeAPI
[BITS 16]                    ; Real Mode code (16 bit)
    mov bx, SECTOR_BUFFER
    mov ax, 0x0301            ; write 1 sector
    int 0x13
    cli                        ; BIOS might have left interrupts enabled
    call setProtectedModeAPI   ; called from 16 bit code, returns to 32 bit code
[BITS 32]                    ; Protected Mode code (32 bit)
    ret

    times (0x400 - ($ - $$)) nop

; *****
; *****
; After Two Sectors
; *****
; *****

version:
    db 'cf2022 1v0 2022Sep24 Chuck Moore' , 0x00    ; 0x20 + 1 bytes
    db ' Howerd Oakford inventio.co.uk' , 0x00      ; 0x1E + 1 bytes, total 0x40

nul:
    ret

; *****
; Co-operative multi-tasker with comments from code by Josh Grams
; *****

; This version of colorforth has three tasks; main (the quit loop),
; draw (user defined), and serve (also user defined). Each has two
; grows-down stacks. A suffix of 's' indicates the return stack, 'd'
; indicates the data stack. Thus 'draws' and 'drawd' are the tops of
; the return and data stacks, respectively, for the draw task.

; When we switch tasks, we need to switch stacks as well. We do this
; by pushing eax (cached top-of-stack) onto the data stack, pushing
; the data stack pointer onto the return stack, and then saving the
; return stack pointer into the save slot for the task.

; 'me' points to the save slot for the current task
me:
    dd main
x_screenTask:
    dd nul
x_serverTask:
    dd nul
x_serverTask2:
    dd nul

pause_:
    _DUP_
    push esi
    mov _TOS_, [ me ]          ; points to main at startup
    mov [_TOS_], esp
    add _TOS_, byte 0x04
    jmp _TOS_

resume:
    pop _TOS_
    mov esp, [_TOS_]
    mov [ me ], _TOS_
    pop esi
    _DROP_
    ret

; these are the save slots - each is followed by code to resume the
; next task - the last one jumps 'round to the first.

```

```

round:
    call resume
main:                                ; main task
    dd 0                            ; new stack location
    call resume
draw:                                ; screen draw task
    dd 0                            ; new stack location
    call resume
serv1:                               ; server task
    dd 0                            ; new stack location
    call resume
serv2:                               ; server task 2
    dd 0                            ; new stack location
    jmp short round                 ; loop forever between 3 stacks

activate: ; ( a -- ) \ activate the draw task to execute colorForth code at the given address
    mov edx, DATA_STACK_1 - 4
    mov [edx], ecx
    mov ecx, RETURN_STACK_1 - 4
    pop dword [ecx]
    lea ecx, [ ecx - 0x04 ]
    mov [ecx], edx
    mov dword [ draw ], ecx
    _DROP_
    ret

show: ; ( -- ) \ set the screen task to execute the code following show
    pop dword [ x_screenTask ]      ; copy the return address of the calling word into the screenTask
variable
    _DUP_
    xor _TOS_, _TOS_
    call activate
.back:
    call graphAction                ; perform a graphical update
    call [ x_screenTask ]           ; execute the code that called show, saved on entry
    call switch                     ; copy the screen image to the VESA buffer
    xor _TOS_, _TOS_
    call pause_
    inc _TOS_
    jmp short .back

initshow:                           ; called by warm
    call show
    ; <--- this address ( on the return stack from the preceding call ) goes into x_screenTask
    ret                             ; makes this a no-op "show"

freeze:
    pop dword [ x_screenTask ]
    _DUP_
    xor _TOS_, _TOS_
    call activate
.back:
    ; call graphAction                ; perform a graphical update
    call [ x_screenTask ]           ; execute the code that called show, saved on entry
    ; call switch                     ; copy the screen image to the VESA buffer
    xor _TOS_, _TOS_
    call pause_
    inc _TOS_
    jmp short .back

; *****
; ; Server task 1
; *****

activate1: ; ( a -- ) \ activate the server task to execute colorForth code at the given address
    mov edx, DATA_STACK_2 - 4
    mov [edx], ecx
    mov ecx, RETURN_STACK_2 - 4
    pop dword [ecx]
    lea ecx, [ ecx - 0x04 ]

```

```

    mov [ecx], edx
    mov [ serv1 ], ecx
    _DROP_
    ret

serv1_:
    pop dword [ x_serverTask ]
    call activate1
.back:
    ; call graphAction                ; perform a graphical update
    call [ x_serverTask ]             ; execute the code that called show, saved on entry
    ; call switch                    ; copy the screen image to the VESA buffer
    xor _TOS_, _TOS_
    call pause_
    inc _TOS_
    jmp short .back

initserv1_:
    call serv1_
    ret

; *****
; Server task 2
; *****

activate2: ; ( a -- ) \ activate the server task to execute colorForth code at the given address
    mov edx, DATA_STACK_3 - 4
    mov [edx], ecx
    mov ecx, RETURN_STACK_3 - 4
    pop dword [ecx]
    lea ecx, [ ecx - 0x04 ]
    mov [ecx], edx
    mov [ serv2 ], ecx
    _DROP_
    ret

serv2_:
    pop dword [ x_serverTask2 ]
    call activate2
.back:
    ; call graphAction                ; perform a graphical update
    call [ x_serverTask2 ]           ; execute the code that called show, saved on entry
    ; call switch                    ; copy the screen image to the VESA buffer
    xor _TOS_, _TOS_
    call pause_
    inc _TOS_
    jmp short .back

initserv2_:
    call serv2_
    ret

; *****
; *****

c_: ; ( -- ) \ clear the data stack for keyboard task
    mov esi, ( DATA_STACK_0 + 4 )
    ret

; *****
; *****

mark:
    mov ecx, [ v_MacroWordCount]
    mov [ mark_MacroWordCount], ecx
    mov ecx, [ v_ForthWordCount ]
    mov [ mark_v_ForthWordCount], ecx
    mov ecx, [ v_H ]
    mov [ mark_H ], ecx
    ret

```

```

empty_:
    cli                                ; disable interrupts
    call initerv1_                     ; we must set the server tasks to their Nop loop
    call initerv2_                     ; because the code that they might be running will soon be gone...
    mov ecx, [ mark_H ]
    mov [ v_H ], ecx
    mov ecx, [ mark_v_ForthWordCount ]
    mov [ v_ForthWordCount ], ecx
    mov ecx, [ mark_MacroWordCount ]
    mov [ v_MacroWordCount ], ecx
    mov dword [ class ], 0x00
    ret

; *****
; *****

mfind: ; ( sf -- ) \ ecx = index ; find the Shannon-Fano word sf in the Macro wordlist, return its
index in ecx
    mov ecx, [ v_MacroWordCount ] ; count of Macro wordlist words
    push edi
    lea edi, [ ( ecx * 4 ) + MacroNames - 4 ]
    jmp short ffind

find: ; ( sf -- ) \ ecx = index ; find the Shannon-Fano word sf in the Forth wordlist, return its
index in ecx
    mov ecx, [ v_ForthWordCount ] ; count of Forth wordlist words
    push edi
    lea edi, [ ( ecx * 4 ) + ForthNames - 4 ] ; set edi to the top of the Forth name table
ffind:
    std                                ; scan backwards
    repne scasd                        ; locate the 32 bit Shanon-Fano encoded name, compare eax with doubleword at
es:edi and set status flags.
    cld                                ; reset the direction flag
    pop edi
    ret

; *****
; *****

abort:
    jmp dword [ x_abort ]

; *****
; *****

cdrop:
    mov edx, [ v_H ]
    mov [ list ], edx
    mov byte [edx], 0xAD                ; 0xAD is the opcode for 'lods'
    inc dword [ v_H ]
    ret

; *****
; *****

qdup:
    mov edx, [ v_H ]
    dec edx
    cmp dword [ list ], edx
    jnz cdup
    cmp byte [edx], 0xAD                ; 0xAD is the opcode for 'lods'
    jnz cdup
    mov [ v_H ], edx
    ret

cdup: ; compile action of dup macro
    mov edx, [ v_H ]
    mov dword [edx], 0x89FC768D        ; assemble the instruction sequence for DUP "lea esi, [ esi - 4 ]",
"mov [esi], eax"

```

```

    mov byte [ edx + 4 ], 0x006    ; "8d 76 fc" , "89 06" ( the first 4 are expressed in little endian
format above )
    add dword [ v_H ], byte 0x05
    ret

adup:
    _DUP_    ; interpret action of dup macro
    ret

; *****
; *****

sdefine:
    pop dword [ adefine ]
    ret

macro:      ; select the Macro wordlist
    call sdefine
macrod:
    push _TOS_
    mov ecx, [ v_MacroWordCount ]
    inc dword [ v_MacroWordCount ]
    lea ecx, [ ( ecx * 4 ) + MacroNames ]
    mov _TOS_, ( MacroJumpTable - MacroNames ) ; mov _TOS_, 0x218
    jmp short forthdd

forth:      ; select the Forth wordlist
    call sdefine
forthd:
    push _TOS_
    mov ecx, [ v_ForthWordCount ]
    inc dword [ v_ForthWordCount ]
    lea ecx, [ ( ecx * 4 ) + ForthNames ]
    mov _TOS_, ( ForthJumpTable - ForthNames )
forthdd:
    mov edx, [ ( edi * 4 ) - 0x04 ]
    and edx, byte -0x10
    mov [ecx], edx
    mov edx, [ v_H ]
    mov [ecx+_TOS_], edx
    lea edx, [ecx+_TOS_]
    shr edx, 0x02
    mov [ v_last ], edx
    pop _TOS_
    mov [ list ], esp
    mov dword [ lit ], adup
    test dword [ class ], -1
    jz .fthd
    jmp dword [ class ]
.fthd:
    ret

; *****
; *****

var1:      ; interpret time code for magenta variable
    _DUP_
    mov _TOS_, [ 4 + ForthNames + ( ecx * 4 ) ]
    shl _TOS_, 2
    ret

m_variable: ; create a magenta variable
    call forthd
    mov dword [ ForthJumpTable - ForthNames + ecx ], var1
    inc dword [ v_ForthWordCount ]      ; dummy entry for source address
    mov [ 4 + ecx ], edi
    call macrod
    mov dword [ MacroJumpTable - MacroNames + ecx ], .var
    inc dword [ v_MacroWordCount ]
    mov [ 4 + ecx ], edi

```

```

    inc edi
    ret

.var:    ; compile time code for magenta variable in Macro dictionary
    call [ lit ]
    mov _TOS_, [ 4 + MacroNames + ( ecx * 4 ) ]
    shl _TOS_, 2
    jmp short cshrt

; *****
; *****

alit:
    mov dword [ lit ], adup

literal:
    call qdup
    mov edx, [ list ]           ; select the wordlist to add the literal to
    mov [ list + 4 ], edx
    mov edx, [ v_H ]
    mov [ list ], edx
    mov byte [edx], _MOV_TOS_LIT_ ; the opcode for mov eax, 32_bit_literal (in next 32 bit cell)
    mov [ edx + 0x01 ], _TOS_    ; the literal value follows in the next 4 bytes in the dictionary
    add dword [ v_H ], byte 0x05 ; move the dictionary pointer forward 5 bytes
    ret

; *****
; *****

cnum:
    call [ lit ]
    mov _TOS_, [ ( edi * 4 ) + 0x00 ]
    inc edi
    jmp short cshrt

cshort:
    call [ lit ]
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    sar _TOS_, 0x05

cshrt:
    call literal
    _DROP_
    ret

; *****
; *****

ex1:
    xor edi, edi

.back:
    dec dword [ v_words ]
    jz ex2
    _DROP_
    jmp short .back

execute_lit:    ; ( -- )
    mov dword [ lit ], alit
    _DUP_
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
execute:    ; ( name -- )
    and _TOS_, byte -0x10

ex2:
    call find_
    jnz abort
    _DROP_
    jmp dword [ ( ecx * 4 ) + ForthJumpTable ]

; *****
; *****

```

```

qcompile:
    call [ lit ]
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    and _TOS_, byte -0x10
    call mfind
    jnz .forward
    _DROP_
    jmp dword [ ( ecx * 4 ) + MacroJumpTable ]
.forward:
    call find_
    mov _TOS_, [ ( ecx * 4 ) + ForthJumpTable ]

qcom1:
    jnz abort
call_:
    mov edx, [ v_H ]
    mov [ list ], edx
    mov byte [edx], 0xE8      ; 0xE8 is the opcode for 'call immediate'
    add edx, byte 0x05
    sub _TOS_, edx
    mov [ edx - 0x04 ], _TOS_
    mov [ v_H ], edx
    _DROP_
    ret

; *****
; *****

compile:
    call [ lit]
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    and _TOS_, byte -0x10
    call mfind
    mov _TOS_, [ ( ecx * 4 ) + MacroJumpTable ]
    jmp short qcom1

; *****
; *****

short_:
    mov dword [ lit], alit
    _DUP_
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    sar _TOS_, 0x05
    ret

; *****
; *****

num:
    mov dword [ lit], alit
    _DUP_
    mov _TOS_, [ ( edi * 4 ) + 0x00 ]
    inc edi
    ret

; *****
; *****

comma_:
    ; 4 byte ,
    mov ecx, 0x04
dcomma:
    ; c, performed n times ( n in ecx )
    mov edx, [ v_H ]
    mov [edx], _TOS_
    mov _TOS_, [ esi ]
    lea edx, [ ecx + edx ]
    lea esi, [ esi + 0x04 ]
    mov [ v_H ], edx
    ret

```



```

comma1_:    ; 1 byte  c,
            mov ecx, 0x01
            jmp short dcomma

comma2_:    ; 2 byte  w,
            mov ecx, 0x02
            jmp short dcomma

comma3_:    ; 3 byte  c, c, c,
            mov ecx, 0x03
            jmp short dcomma

; *****
; *****

semicolon:
    mov edx, [ v_H ]
    sub edx, byte 0x05
    cmp [ list ], edx
    jnz .forward
    cmp byte [edx], 0xE8          ; 0xE8 is the opcode for 'call immediate'
    jnz .forward
    inc byte [edx]
    ret
.forward:
    mov byte [ edx + 0x05 ], 0xC3 ; 0xC3 is the opcode for 'ret'
    inc dword [ v_H ]
    ret

; *****
; *****

then:
    mov [ list ], esp
    mov edx, [ v_H ]
    sub edx, _TOS_
    mov [ _TOS_ - 0x01 ], dl
    _DROP_
    ret

begin_:
    mov [ list ], esp
here:
    _DUP_
    mov _TOS_, [v_H]
    ret

; *****
; *****

qlit: ; ?lit
    mov edx, [ v_H ]
    lea edx, [ edx - 0x05 ]
    cmp [ list ], edx
    jnz .forward
    cmp byte [edx], _MOV_TOS_LIT_ ; the opcode for mov eax, 32_bit_literal (in next 32 bit cell)
    jnz .forward
    _DUP_
    mov _TOS_, [ list + 4 ]
    mov [ list ], _TOS_
    mov _TOS_, [ edx + 0x01 ]
    cmp dword [ edx - 5 ], 0x89FC768D ; assemble code 8D 76 FC 89 rr => lea esi, [ esi - 0x04 ] ; mov [
esi ], register
; like dup but with the register value still to follow in the next byte
    jz .forward2
    mov [ v_H ], edx
    jmp dword cdrop
.forward2:
    add dword [ v_H ], byte -0x0A
    ret

```

```

.forward:
    xor edx, edx
    ret

less:
    cmp [ esi ], _TOS_
    js .forward
    xor ecx, ecx
.forward:
    ret

qignore:
    test dword [ ( edi * 4 ) - 0x04 ], 0xFFFFFFFF0
    jnz .forward
    pop edi
    pop edi
.forward:
    ret

jump:
    pop edx
    add edx, _TOS_
    lea edx, [ edx + ( _TOS_ * 4 ) + 0x05 ]
    add edx, [ edx - 0x04 ]
    _DROP_
    jmp edx

; convert block start address to cell address, add the RELOCATED colorForth system base
blockToCellAddress: ; ( blk -- a' ) \ add the RELOCATED offset and convert to cell address
    add _TOS_, [ v_offset ] ; add the RELOCATED block number offset
    shl _TOS_, 0x08 ; convert to cell address
    ret

cellAddressToBlock: ; ( a -- blk ) \ convert cell address to block number and subtract the RELOCATED
block number offset
    shr _TOS_, 0x08 ; convert cell address to block number
    sub _TOS_, [ v_offset ] ; subtract the block number of block 0
    ret

_load: ; ( blk -- ) \ load the given block number
    call blockToCellAddress ; add the RELOCATED block number offset and convert to cell address
    push edi
    mov edi, _TOS_
    _DROP_
interpret:
    mov edx, [ ( edi * 4 ) + 0x00 ]
    inc edi
    and edx, byte 0x0F
    call [ ( edx * 4 ) + tokenActions ]
    jmp short interpret

    align 4, db 0 ; fill the gap with 0's

; : r@ qdup $8B 1, $C7 1, ; \ mov _TOS_, edi also db 0x89, 0xF8
; : nload r@ $0100 / #2 + load ;
; : +load ( n -- ) r@ $0100 / + load ;
nload: ; ( -- ) \ load the next source block following the one currently being loaded
    call cblk_
    add _TOS_, 0x02
    jmp _load_

plusload: ; ( n -- ) \ load the n'th source block following the one currently being loaded
    mov _SCRATCH_, _TOS_ ; save the required offset
    _DROP_
    call cblk_
    add _TOS_, _SCRATCH_
    jmp _load_

; : THRU ( f l -- ) 1+ SWAP DO I LOAD LOOP ;
thru_: ; ( first last -- ) \ load from the first to the last block

```

```

    add _TOS_, 0x02
    mov _SCRATCH_, _TOS_
    _DROP_ ; TOS = first, SCRATCH = last
    mov ecx, _SCRATCH_
    sub ecx, _TOS_ ; ecx = count
    jz .end ; exit if count is zero
    jc .end ; exit if count is negative
    shr ecx, 1 ; divide by 2, as we skip 2 blocks each time round the loop
.back:
    _DUP_
    _DUP_ ; just to be safe...
    push ecx
    push _SCRATCH_
    call _load_
    pop _SCRATCH_
    pop ecx
    _DROP_ ; just to be safe...
    add _TOS_, 0x02
    loop .back
.end:
    _DROP_
    ret

v_temp:
    dd 0

plusThru_: ; ( first+ last+ -- ) \ load from the first to the last block relative to the current block
being loaded
    call cblk_
    mov [ v_temp ], _TOS_
    _DROP_
    mov _SCRATCH_, [ v_temp ]
    add [ esi ], _SCRATCH_ ; add current block to second on stack
    add _TOS_, _SCRATCH_ ; add current block to top of stack
    call thru_
    ret

cblk_: ; ( -- n ) \ return the currently compiling block number - only valid while compiling
    _DUP_
    mov _TOS_, edi ; edi contains the cell address in the block currently being compiled
    call cellAddressToBlock ; convert to block number relative to block 0
    ret

rblk_: ; ( -- n ) \ return the block number offset of the RELOCATED address
    _DUP_
    mov _TOS_, ( RELOCATED >> ( 2 + 8 ) )
    ret

ablk_: ; ( a -- n ) \ convert byte address to block number
    shr _TOS_, 0x02
    call cellAddressToBlock
    ret

erase_: ; ( a n -- ) \ erase n bytes starting at address a
    mov ecx, eax
    _DROP_
    push edi
    mov edi, eax
    xor eax, eax
    rep stosb
    pop edi
    _DROP_
    ret

v_curs_to_source: ; ( n -- a32 ) \ return the cell address of the current cursor position in the
current block being edited
    mov _SCRATCH_, _TOS_
    mov _TOS_, [ v_blk ] ; get the currently edited block number
    call blockToCellAddress
    add _TOS_, _SCRATCH_ ; add the cursor position (cell address) in the block

```

```

    ret

nth_to_token:  ; ( n -- tok ) \ return the token at the n'th cursor position in the current block being
edited
    call v_curs_to_source
    shl _TOS_, 0x02                ; convert cell address to byte address
    mov _TOS_, [ _TOS_ ]          ; fetch the token
    ret

v_curs_to_token:  ; ( -- tok ) \ return the token at the current cursor position in the current block
being edited
    _DUP_
    mov _TOS_, [ v_blk ]          ; get the currently edited block number
    call nth_to_token
    ret

; : ?f $C021 2, ;
; qf:
;     db 0x21, 0xC0 ; and _TOS_, _TOS_
;     ret

; *****
; *****

top_:  ; ( -- ) \ set the cursor to the left margin horizontally and 3 pixels down from the top
vertically
    mov ecx, [ v_leftMargin ]
    shl ecx, 0x10
    add ecx, byte 0x03
    mov [ v_xy ], ecx
    ; mov [ xycr ], ecx
    ret

qcr: ; ( -- ) \ ?cr do a CR if the cursor has gone past the right margin
    mov cx, [ v_x ]
    cmp cx, [ v_rightMargin ]
    js cr_forward
cr_:  ; ( -- )
    mov ecx, [ v_leftMargin ]
    shl ecx, 0x10
    mov cx, [ v_xy ]
    add cx, [ v_iconh ]
    mov [ v_xy ], ecx
cr_forward:
    ret

green:  ; ( -- )
    _DUP_
    mov _TOS_, colour_green
    jmp color

yellow:  ; ( -- )
    _DUP_
    mov _TOS_, colour_yellow
    jmp color

; red:  ; ( -- ) ; see redWord:
;     _DUP_
;     mov _TOS_, colour_red
;     jmp color

white:  ; ( -- )
    _DUP_
    mov _TOS_, colour_white
color:  ; ( rgb16 -- )
    mov [ v_foregroundColour ], _TOS_
    _DROP_
    ret

```

```

rgb:    ; ( rgb32 -- rgb16 )    ; convert from 32 bit ( 8:8:8:8 _RGB ) colour to 16 bit ( 5:6:5 RGB )
colour value
    ror _TOS_, 8
    shr ax, 2
    ror _TOS_, 6
    shr al, 3
    rol _TOS_, ( 6 + 5 )
    and _TOS_, 0x0000FFFF
    ret

bye_:    ; ( -- ) \ exit colorForth
    call setRealModeAPI
[BITS 16]                                ; Real Mode code (16 bit)
    int 0x19    ; reboot the computer
    ; should never get past this point... but in case we do...
    cli                                ; BIOS might have left interrupts enabled
    call setProtectedModeAPI            ; called from 16 bit code, returns to 32 bit code
[BITS 32]                                ; Protected Mode code (32 bit)
    ret

%if 0
pci:
    mov edx, 0x0CF8
    out dx, _TOS_
    lea edx, [ edx + 0x04 ]
    in _TOS_, dx
    ret

device:
    times ( 0x93a - ( $ - $$ ) ) nop ; fill with nops to find_display ???

find_display:
    mov _TOS_, 0x3000000                ; called by warm
    ; PCI class code 3 = display controller
    call device                        ; returns header address
    lea _TOS_, [ _TOS_ + 0x10 ]        ; point to Base Address #0 (BAR0)
    mov cl, 0x06
.next:
    _DUP_
    call pci
    and al, 0xFB
    xor al, 0x08
    jz .forward
    _DROP_
    lea _TOS_, [ _TOS_ + 0x04 ]
    loop .next
    lea _TOS_, [ _TOS_ - 0x18 ]
    _DUP_
    call pci
    and al, 0xF0
.forward:
    mov [ v_frameBuffer ], _TOS_      ; set framebuffer address
    _DROP_
    ret

fifo:
    _DROP_
    ret

%endif

graphAction:
    ret

; *****
; *****
; graphics mode dependent code
; *****
; *****
; *****

```

```

; 1024x768 display
; *****

scrnw1 equ 1024          ; screen width in pixels
scrnh1 equ 768           ; screen height in pixels
iconw1 equ ( 16 + 4 )    ; icon width
iconh1 equ ( 24 + 4 )    ; icon height for 768 pixel high screen

keypadY1 equ 4           ; location of keyboard display vertically in lines from the bottom

initIconSize1:
    mov dword [ v_iconw ], iconw1
    mov dword [ v_nine_iconw ], ( iconw1 * 9 )
    mov dword [ v_twentytwo_iconw ], ( iconw1 * ( 13 + 9 ) )
    mov dword [ v_10000_iconw ], ( iconw1 * 0x10000 )
    mov dword [ v_iconh ], iconh1
    mov dword [ v_keypadY_iconh ], keypadY1 * iconh1
    ret

switch1:      ; copy our created image to the real display buffer
    push esi
    push edi
    mov esi, dword [ vframe ]      ; vframe points to where we create our image
    mov edi, [ vesa_PhysBasePtr ] ; VESA frame buffer, saved by VESA BIOS call, the address in RAM that
is displayed by the hardware
    mov ecx, ( ( scrnw1 * scrnh1 ) / 4 ) * BYTES_PER_PIXEL ; the / 4 is because we are moving doubles =
4 bytes each
    rep movsd                      ; copy ecx 32 bit words from ds:esi to es:edi
    pop edi
    pop esi
    ret

clip1:
    mov edi, [ v_xy ]
    mov ecx, edi
    test cx, cx
    jns .forward
    xor ecx, ecx
.forward:
    and ecx, 0x0000FFFF
    mov [ v_yc ], ecx
    imul ecx, ( scrnw1 * BYTES_PER_PIXEL )
    sar edi, 16
    jns .forward2
    xor edi, edi
.forward2:
    mov [ v_xc ], edi
    lea edi, [ edi * BYTES_PER_PIXEL + ecx ]
    add edi, [ vframe ]
    ret

bit16:                ; write a 16 x 24 glyph to the graphic screen
    lodsw              ; load the 16 bit value pointed to by SI into ax
    xchg al, ah        ; eax_TOS_
.back:
    shl ax, 0x01       ; eax_TOS_
    jnc .forward
    mov [ edi ], dx
    jmp .forward2
.forward:
    ror edx, 0x10       ; use the background colour, in the high 16 bits
;    mov [ edi ], dx    ;
    ror edx, 0x10       ; return to the foreground colour, in the low 16 bits
.forward2:
    add edi, byte BYTES_PER_PIXEL
    loop .back
    ret

; write the background after the glyph
bit16Background:      ; number of pixels to write in ecx , screen address in edi , colours in edx

```

```

    ror edx, 0x10          ; use the background colour, in the high 16 bits
.back:
;   mov [ edi ], dx        ;
   add edi, byte BYTES_PER_PIXEL
loop .back
ror edx, 0x10             ; return to the foreground colour, in the low 16 bits
ret

bit32:                    ; write a 32 x 48 double size glyph to the graphic screen
lodsw                     ; load the 16 bit value pointed to by SI into ax
xchg al, ah               ; eax_TOS_
mov ecx, 0x10
.back:
shl _TOS_, 1              ; eax_TOS_
jnc .forward
mov [ edi ], dx
mov [ edi + BYTES_PER_PIXEL ], dx

cmp byte [ displayMode ], 0
jnz .width2
mov [ edi + ( scrnw1 * BYTES_PER_PIXEL ) ], dx
mov [ edi + ( scrnw1 * BYTES_PER_PIXEL ) + BYTES_PER_PIXEL ], dx
jmp .widthEnd

.width2:
mov [ edi + ( scrnw2 * BYTES_PER_PIXEL ) ], dx
mov [ edi + ( scrnw2 * BYTES_PER_PIXEL ) + BYTES_PER_PIXEL ], dx
.widthEnd:
.forward:
add edi, byte ( BYTES_PER_PIXEL * 2 )
loop .back
ret

; Table that maps the three levels of Shannon-Fano codes to ASCII, followed by a copy in Capitalised or larger form
; The original colorForth font has "capital numbers" - larger bold versions, all offset by 0x30 from the normal ones.
; The new font maps the "larger forms" to offset 0x80, i.e. $30 --> $B0, two forms of '0'.
ShannonFano:
    000000001111111122222222222222222222222222222222 <- levels
;   0123456789ABCDEF0123456789ABCDEF0123456789ABCDEF0123456789ABCDEF01234567 <- index
db 0x00           ; a space in the cf font
;   0123456789ABCDEF0123456789ABCDEF0123456789ABCDEF0123456789ABCDEF01234567 <- index
db "rtoeanismcylgfwdvpbhxuq0123456789j-k.z/;'!+@*,? RTOEANISMCYLGFWDPVBHXUQ" ; ASCII equivalents
;   89ABCDEFO1
db 0xB0,0xB1,0xB2,0xB3,0xB4,0xB5,0xB6,0xB7,0xB8,0xB9; larger "capital"forms of "0123456789"
;   23456
db "J_K.Z"       ; normal capitals
;   789ABCDEFGH
db 0xAF,0xBB,0xA7,0xA1,0xAB,0xC0,0xAA,0xAC,0xBF; larger "capital" forms of "/;'!+@*,?"
;   0123456789ABCDEF0123456789ABCDEF
db 0x10,0x11,0x12,0x13,0x23,0x14,0x15,0x16,0x5B,0x5D,0x17,0x18,0x19,0x28,0x29,0x2A ; $60
....#...[ ]...()$

emit1:      ; ( c -- ) \ display a single width and height character
call qcr
push esi
push edi
push edx
imul _TOS_, byte 16*24/8
mov esi, [ v_font ]
add esi, _TOS_
call clip1
mov edx, [ v_foregroundColour ]
mov ecx, 0x18     ; 24 lines
.back:
push ecx
mov ecx, 0x10
call bit16
mov ecx, 0x04
push edi
```

```

    call bit16Background
    pop edi
    pop ecx
    add edi, ( scrnw1 - 16 ) * BYTES_PER_PIXEL ; address of the next line of the glyph
    loop .back ; next horizontal line

    mov ecx, 0x04 ; 4 background lines
.back2:
    push ecx
    mov ecx, 0x10
    call bit16Background
    mov ecx, 0x04
    push edi
    call bit16Background
    pop edi
    pop ecx
    add edi, ( scrnw1 - 16 ) * BYTES_PER_PIXEL ; address of the next line of the glyph
    loop .back2 ; next horizontal line

    pop edx
    pop edi
    pop esi
    _DROP_
space1:
    add dword [ v_xy ], iconw1 * 0x10000 ; 22 horizontal pixels
    ret

two_emit1: ; double width and height character
    push esi
    push edi
    push edx
    imul _TOS_, byte 16*24/8
    mov esi, [ v_font ]
    add esi, _TOS_
    call clip1
    mov edx, [ v_foregroundColour ]
    mov ecx, 0x18 ; 24 lines
.back:
    push ecx
    call bit32
    add edi, (2*scrnw1-16*2)*BYTES_PER_PIXEL
    pop ecx
    loop .back
    pop edx
    pop edi
    pop esi
    add dword [ v_xy ], iconw1 * 2 * 0x10000 ; 44 horizontal pixels
    _DROP_
    ret

setupText_1: ; setup for full screen text window display
    call white
    mov dword [ v_leftMargin ], 0x03
    mov dword [ v_rightMargin ], ( scrnw1 - iconw1 )
    jmp dword top_

box1: ; ( width height -- )
    call clip1
    cmp _TOS_, scrnh1+1
    js .forward
    mov _TOS_, scrnh1
.forward:
    mov ecx, _TOS_
    sub ecx, [ v_yc ]
    jng .forward3
    cmp dword [esi], scrnw1+1
    js .forward2
    mov dword [esi], scrnw1
.forward2:
    mov _TOS_, [ v_xc ]

```



```

    sub [esi], _TOS_
    jng .forward3
    mov edx, scrnw1
    sub edx, [esi]
    shl edx, PIXEL_SHIFT
    mov _TOS_, [ v_foregroundColour ]
.back:
    push ecx
    mov ecx, [esi]
    rep stosw ; stosw depends on BYTES_PER_PIXEL, either stosw or stosd
    add edi, edx
    pop ecx
    loop .back
.forward3:
    _DROP_
    _DROP_
    ret

wash1: ; ( colour -- ) \ fill the full screen with the given colour
    call color
    _DUP_

    xor _TOS_, _TOS_ ; x,y = 0,0 top left corner
    mov [ v_xy ], _TOS_

    mov _TOS_, scrnw1
    _DUP_
    mov _TOS_, scrnh1
    jmp dword box_

; *****
; 800x600 screen
; *****

scrnw2 equ 800 ; screen width in pixels
scrnh2 equ 600 ; screen height in pixels
iconw2 equ ( 16 + 1 ) ; icon width
iconh2 equ ( 24 - 1 ) ; icon height for NC10 600 pixel high screen

keypadY2 equ 4 ; location of keyboard display vertically in lines from the bottom

initIconSize2:
    mov dword [ v_iconw ], iconw2
    mov dword [ v_nine_iconw ], ( iconw2 * 9 )
    mov dword [ v_twentytwo_iconw ], ( iconw2 * ( 13 + 9 ) )
    mov dword [ v_10000_iconw ], ( iconw2 * 0x10000 )
    mov dword [ v_iconh ], iconh2
    mov dword [ v_keypadY_iconh ], keypadY2 * iconh2
    ret

switch2: ; copy our created image to the real display buffer
    push esi
    push edi
    mov esi, dword [ vframe ] ; vframe points to where we create our image
    mov edi, [ vesa_PhysBasePtr ] ; VESA frame buffer, saved by VESA BIOS call, the address in RAM that
is displayed by the hardware
    mov ecx, ( ( scrnw2 * scrnh2 ) / 4 ) * BYTES_PER_PIXEL ; the / 4 is because we are moving doubles =
4 bytes each
    rep movsd ; copy ecx 32 bit words from ds:esi to es:edi
    pop edi
    pop esi
    ret

clip2:
    mov edi, [ v_xy ]
    mov ecx, edi
    test cx, cx
    jns .forward
    xor ecx, ecx
.forward:

```

```

    and ecx, 0x0000FFFF
    mov [ v_yc ], ecx
    imul ecx, ( scrnw2 * BYTES_PER_PIXEL )
    sar edi, 16
    jns .forward2
    xor edi, edi
.forward2:
    mov [ v_xc ], edi
    lea edi, [ edi * BYTES_PER_PIXEL + ecx ]
    add edi, [ vframe ]
    ret

emit2:      ; ( c -- ) \ display a single width and height character
    call qcr
    push esi
    push edi
    push edx
    imul _TOS_, byte 16*24/8
    mov esi, [ v_font ]
    add esi, _TOS_
    call clip2
    mov edx, [ v_foregroundColour ]
    mov ecx, 0x18 ; 24 lines
.back:
    push ecx
    mov ecx, 0x10
    call bit16
    mov ecx, 0x04
    push edi
    call bit16Background
    pop edi
    pop ecx
    add edi, ( scrnw2 - 16 ) * BYTES_PER_PIXEL ; address of the next line of the glyph
    loop .back ; next horizontal line

    mov ecx, 0x04 ; 4 background lines
.back2:
    push ecx
    mov ecx, 0x10
    call bit16Background
    mov ecx, 0x04
    push edi
    call bit16Background
    pop edi
    pop ecx
    add edi, ( scrnw2 - 16 ) * BYTES_PER_PIXEL ; address of the next line of the glyph
    loop .back2 ; next horizontal line

    pop edx
    pop edi
    pop esi
    _DROP_
space2:
    add dword [ v_xy ], iconw2 * 0x10000 ; 22 horizontal pixels
    ret

two_emit2: ; double width and height character
    push esi
    push edi
    push edx
    imul _TOS_, byte 16*24/8
    mov esi, [ v_font ]
    add esi, _TOS_
    call clip2
    mov edx, [ v_foregroundColour ]
    mov ecx, 0x18 ; 24 lines
.back:
    push ecx
    call bit32
    add edi, (2*scrnw2-16*2)*BYTES_PER_PIXEL

```

```

    pop ecx
    loop .back
    pop edx
    pop edi
    pop esi
    add dword [ v_xy ], iconw2 * 2 * 0x10000 ; 44 horizontal pixels
    _DROP_
    ret

setupText__2:    ; setup for full screen text window display
    call white
    mov dword [ v_leftMargin ], 0x03
    mov dword [ v_rightMargin ], ( scrnw2 - iconw2 )
    jmp dword top_

box2: ; ( width height -- )
    call clip2
    cmp _TOS_, scrnh2+1
    js .forward
    mov _TOS_, scrnh2
.forward:
    mov ecx, _TOS_
    sub ecx, [ v_yc ]
    jng .forward3
    cmp dword [esi], scrnw2+1
    js .forward2
    mov dword [esi], scrnw2
.forward2:
    mov _TOS_, [ v_xc ]
    sub [esi], _TOS_
    jng .forward3
    mov edx, scrnw2
    sub edx, [esi]
    shl edx, PIXEL_SHIFT
    mov _TOS_, [ v_foregroundColour ]
.back:
    push ecx
    mov ecx, [esi]
    rep stosw ; stosw depends on BYTES_PER_PIXEL, either stosw or stosd
    add edi, edx
    pop ecx
    loop .back
.forward3:
    _DROP_
    _DROP_
    ret

wash2:    ; ( colour -- ) \ fill the full screen with the given colour
    call color
    _DUP_

    xor _TOS_, _TOS_ ; x,y = 0,0 top left corner
    mov [ v_xy ], _TOS_

    mov _TOS_, scrnw2
    _DUP_
    mov _TOS_, scrnh2
    jmp dword box_

; *****
; select which display mode code to use
; *****

displayMode:
    dd 1 ; 0 = 1024x768x16, 1 = 800x600x16

initIconSize: ; sets up the size of an icon (glyph) according to the 800x600 or 1024x768 display size
    cmp byte [ displayMode ], 0
    jz initIconSize1
    jmp initIconSize2

```

```

switch:
    cmp byte [ displayMode ], 0
    jz switch1
    jmp switch2

clip:
    cmp byte [ displayMode ], 0
    jz clip1
    jmp clip2

emitSF_:
    mov al, [ ShannonFano + _TOS_ ]
emit_:    ; ( c -- ) display byte c on the screen
    cmp byte [ displayMode ], 0
    jz emit1
    jmp emit2

space_:
    cmp byte [ displayMode ], 0
    jz space1
    jmp space2

type_:    ; ( a n -- ) display n bytes at address a on the screen
    mov ecx, _TOS_
    _DROP_
    mov _SCRATCH_, _TOS_
    .back:
        pusha
        _DUP_
        mov al, [ _SCRATCH_ ]
        and _TOS_, 0x000000FF
        call emit_
        popa
        inc _SCRATCH_
    loop .back
    _DROP_
    ret

; double size versions of emit, 32 x 48 pixels per glyph
two_emit_SF:
    mov al, [ ShannonFano + _TOS_ ]
two_emit:
    cmp byte [ displayMode ], 0
    jz two_emit1
    jmp two_emit2

setupText_:    ; setup for full screen text window display
    cmp byte [ displayMode ], 0
    jz setupText__1
    jmp setupText__2

line_:    ; ( startX length -- ) \ draw a horizontal line in the current colour, from startX relative to
current clip window, of given length in pixels
    cmp byte [ displayMode ], 0
    jnz .forward
    call clip1
    jmp .common
.forward:
    call clip2
.common:
    mov ecx, [esi]
    shl ecx, PIXEL_SHIFT
    sub edi, ecx
    mov ecx, _TOS_
    mov _TOS_, [ v_foregroundColour ]
    rep stosw ;
    inc dword [ v_xy ]
    _DROP_
    _DROP_

```

```

    ret

box_:
    cmp byte [ displayMode ], 0
    jz box1
    jmp box2

page_:    ; ( -- )    \ fill the full screen with the current background colour
    _DUP_
    mov _TOS_, colour_background ;
    jmp wash_

screen_:  ; ( -- )    \ fill the full screen with the current foreground colour
    _DUP_
    mov _TOS_, [ v_foregroundColour ] ;    ; select the foreground colour in the low 16 bits
;    jmp wash_    ; fall through to wash1

wash_:    ; ( colour -- )    \ fill the full screen with the given colour
    mov [ v_washColour ], _TOS_
    cmp byte [ displayMode ], 0
    jz wash1
    jmp wash2

; *****
; *****
; *****

setCyan:
    _DUP_
    mov _TOS_, colour_cyan
    jmp dword color

setMagenta:
    _DUP_
    mov _TOS_, colour_magenta
    jmp dword color

setMagentaData:
    _DUP_
    mov _TOS_, colour_magentaData
    jmp dword color

setBlue:
    _DUP_
    mov _TOS_, colour_blue
    jmp dword color

setRed:
    _DUP_
    mov _TOS_, colour_red
    jmp dword color

setGreen:
    _DUP_
    mov _TOS_, colour_green
    jmp dword color

setSilver:
    _DUP_
    mov _TOS_, colour_silver
    jmp dword color

history:
    times 11 db 0

echo_:
    push esi
    mov ecx, 11-1
    lea edi, [ history ]
    lea esi, [ edi + 1 ]

```

```

    rep movsb
    pop esi
    mov byte [ history+11-1 ], al
    _DROP_
    ret

right:
    _DUP_
    mov ecx, 11
    lea edi, [history]
    xor _TOS_, _TOS_
    rep stosb
    _DROP_
    ret

down:
    _DUP_
    xor edx, edx
    mov ecx, [ v_iconh ]
    div ecx
    mov _TOS_, edx
    sub edx, [ v_iconh ]
    add edx, ( 3 * 0x10000 )+ 0x8000 + 3
    mov [ v_xy ], edx
; zero:
    test _TOS_, _TOS_
    mov _TOS_, 0
    jnz .dw
    inc _TOS_
.dw:
    ret

lm:    ; ( leftMargin -- )
    mov [ v_leftMargin ], _TOS_
    _DROP_
    ret

rm:    ; ( rightMargin -- )
    mov [ v_rightMargin ], _TOS_
    _DROP_
    ret

_at:   ; ( y x -- )
    mov word [ v_y ], ax
    _DROP_
    mov word [ v_x ], ax
    _DROP_
    ret

plus_at: ; ( y x -- )
    add word [ v_y ], ax
    _DROP_
    add word [ v_x ], ax
    _DROP_
    ret

storew_: ; ( w a -- ) \ ; : !w a! $00028966 3, drop ;
    db 0x8B, 0xD0          ; mov edx, eax      a! $D08B 2, ( ?lit not true )
    db 0x66, 0x89, 0x02    ; mov [edx], ax     $00028966 3,
    _DROP_                ; lodsd
    ret                   ; ret

storeu_: ; ( u a -- ) \ ; : !l a! $0289 2, drop ; forth
    db 0x8B, 0xD0          ; mov edx, eax      a! $D08B 2, ( ?lit not true )
    db 0x89, 0x02          ; mov [edx], eax     $0289 2,
    _DROP_                ; lodsd
    ret                   ; ret

uplus_: ; ( u u -- u ) \ : u+ ?lit if $0681 2, , ; then $00044601 3, drop ;
    db 0x01, 0x46, 0x04    ; add [esi+0x4], eax $00044601 3, ( ?lit not true )

```

```

    _DROP_                ; lodsd
    ret                   ; ret

%if 1
; the various pieces of code used by a! and +! in colorForth blocks 22 and 24
plusStore: ; ( n a -- )
    ; : a! ?lit if $BA 1, , ; then $D08B 2, drop ;
    mov dword edx, 0x12345678                ; db 0xBA, 0x78, 0x56, 0x34, 0x12
    mov edx, _TOS_                          ; db 0x8B, 0xD0 == db 0x89, 0xC2
    ; : +! ?lit if ?lit if $0581 2, swap a, , ; then $0501 2, a, drop ; then a! $0201 2, drop ;
    add [ dword 0x12345678 ], _TOS_          ; db 0x01, 0x05, 0x78, 0x56, 0x34, 0x12
    add dword [ dword 0x12345678 ], 0x98765432 ; db 0x81, 0x05, 0x78, 0x56, 0x34, 0x12, 0x32, 0x54, 0x76,
0x98
    add [ edx ], _TOS_                      ; db 0x01, 0x02
    ret
%endif

octant:
    _DUP_
    mov _TOS_, 0x43
    mov edx, [ esi + 0x04 ]
    test edx, edx
    jns .forward
    neg edx
    mov [ esi + 0x04 ], edx
    xor al, 0x01
.forward:
    cmp edx, [ esi ]
    jns .forward2
    xor al, 0x04
.forward2:
    ret

hicon:
    db 0x30, 0x31, 0x32, 0x33
    db 0x34, 0x35, 0x36, 0x37
    db 0x38, 0x39, 0x61, 0x62
    db 0x63, 0x64, 0x65, 0x66
    ; db 0x18, 0x19, 0x1A, 0x1B, 0x1C, 0x1D, 0x1E, 0x1F
    ; db 0x20, 0x21, 0x05, 0x13, 0x0A, 0x10, 0x04, 0x0E

edig1:
    _DUP_
digit:
    push ecx
    mov al, [ _TOS_ + hicon ]
    call emit_
    pop ecx
    ret

odig:
    rol _TOS_, 0x04
    _DUP_
    and _TOS_, byte 0x0F
    ret

h_dot_n:
    mov edx, _TOS_
    neg _TOS_
    lea ecx, [ ( _TOS_ * 4 ) + 0x20 ]
    _DROP_
    rol _TOS_, cl
    mov ecx, edx
    jmp short h_dot_one

dotHex8_: ; ( u -- ) \ display a hexadecimal number with leading zeros, 8 .hex
    mov ecx, 0x08
h_dot_one:
    call odig
    call digit

```

```

loop h_dot_one
_DROP_
ret

dotHex2_ ; ( c -- ) \ display a hexadecimal number with leading zeros, 2 .hex
shl _TOS_, 24
mov ecx, 0x02
call h_dot_one
ret

dotHex4_ ; ( w -- ) \ display a hexadecimal number with leading zeros, 4 .hex
shl _TOS_, 16
mov ecx, 0x04
call h_dot_one
ret

dotHex: ; ( u -- ) \ display a hexadecimal number
EMIT_IMM('$')
mov ecx, 0x07
.back:
call odig
jnz .forward
_DROP_
loop .back
inc ecx
.back2:
call odig
.back3:
call digit
loop .back2
call space_
_DROP_
ret
.forward:
inc ecx
jmp short .back3

qdot: ; ( u -- ) \ display a decimal or hexadecimal number, depending on base
cmp dword [ base ], byte 10
jnz dotHex
dotDecimal: ; display a decimal number
; EMIT_IMM('#')
mov edx, _TOS_
test edx, edx
jns .forward
neg edx ; negate the value and display a minus sign if required
EMIT_IMM('-')
.forward:
mov ecx, 0x08
.back:
mov _TOS_, edx
xor edx, edx
div dword [ ecx * 4 + tens ]
test _TOS_, _TOS_
jnz .forward2
dec ecx
jns .back
jmp short .forward3
.back2:
mov _TOS_, edx
xor edx, edx
div dword [ ecx * 4 + tens ]
.forward2:
call edig1
dec ecx
jns .back2
.forward3:
mov _TOS_, edx
call edig1
call space_

```



```

    _DROP_
    ret

eight:    ; display eight characters for one long line in a keypad mnemonic, with a space between the groups
of four
    add edi, byte 0x0C
    call four
    call space_
    sub edi, byte 0x10
four:      ; display four characters for one line in a keypad mnemonic
    mov ecx, 0x04
four1:     ; set ecx to the required number of characters to display
    push ecx
    _DUP_
    xor _TOS_, _TOS_
    mov al, [edi+0x04]
    inc edi
    call emit_
;    call emitSF_    ; Note : The characters returned by a keypad are Shannon-Fano encoded
    pop ecx
    loop four1
    ret

displayTheStack:    ; display the stack
    mov edi, ( DATA_STACK_0 - 4 )    ; save empty stack pointer, plus one ( stack grows downwards )
.back:
    mov edx, [ main ]                ; copy the current stack pointer
    cmp [edx], edi
    jnc .forward                    ; test for empty stack, meaning done
    _DUP_
    mov _TOS_, [edi]                ; fetch the value of the current stack item
    sub edi, byte 0x04                ;
    call qdot                        ; display one stack item
    jmp short .back                ; next stack item
.forward:
    ret

yShift equ 3

displayBlockNumber:    ; ( -- )    ; in the top right corner of the screen
    _DUP_
    mov _TOS_, [ v_foregroundColour ]
    _DUP_
    mov _TOS_, [ vesa_XResolution ]    ; was this : mov _TOS_, ( scrnw )
    and _TOS_, 0xFFFF
    sub _TOS_, [ v_nine_iconw ]
    mov _SCRATCH_, _TOS_                ; save for later
    mov [ v_leftMargin ], _TOS_
    mov [ word v_y ], ax
    add _TOS_, [ v_nine_iconw ]
    mov [ v_rightMargin ], _TOS_
    mov _TOS_, _SCRATCH_
    shl _TOS_, 16
    add _TOS_, yShift
    mov [ v_xy ], _TOS_
    _DUP_
    mov _TOS_, [ v_washColour ]    ; so we do not see the number yet, just measure its width
;    mov _TOS_, colour_blockNumber
;    shr _TOS_, 16                ; select the background colour in the high 16 bits
    call color
    _DUP_
    mov _TOS_, [ v_blk ]
    call qdot
    mov _SCRATCH_, [ v_xy ]                ; current x,y coordinate, x in high 16 bits
    shr _SCRATCH_, 16
    sub _SCRATCH_, [ v_leftMargin ]    ; _SCRATCH_ is now the width of number string, in pixels
    sub _SCRATCH_, [ v_iconw ]        ; correction...
    shl _SCRATCH_, 16
    mov _TOS_, [ vesa_XResolution ]    ; screen width in pixels
;    and _TOS_, 0xFFFF            ; not needed because of the shl below

```

```

    shl _TOS_, 16
    add _TOS_, yShift
    sub _TOS_, _SCRATCH_
    mov [ v_xy ], _TOS_

    _DUP_
    mov _TOS_, colour_blockNumber
    ror _TOS_, 16
    call color
    _DUP_
    mov _TOS_, [ v_iconw ]
    add _TOS_, _TOS_
    _DUP_
    mov _TOS_, [ v_iconh ]
    call box_
    mov [ v_xy ], _TOS_

    mov _TOS_, colour_blockNumber
    _DUP_
    call color
    _DUP_
    mov _TOS_, [ v_blk ]
;    mov _TOS_, [ v_numberOfMagentas ]

    call qdot
    _DROP_
    mov [ v_foregroundColour ], _TOS_
    _DROP_
ret

; *****
; keyboard displays
; *****

showEditBox:    ; v_at set up for start coordinate of box, width and height on stack
    sub dword [ v_xy ], 0x000C0004 ; move the start position left and up by 0xXXXXYYY
    mov dword _SCRATCH_, [ v_foregroundColour ]
    mov dword [ v_foregroundColour ], colour_orange
    mov ecx, 2
.loop:
    push ecx
    _DUP_
    mov _TOS_, 0 ; SOS = x start position in pixels, relative to current clip "window"
    _DUP_
    mov _TOS_, [ v_iconw ]
    shl _TOS_, 3 ; multiply by 8
    add _TOS_, [ v_iconw ] ; multiply by 9
    add _TOS_, [ v_iconw ] ; multiply by 10
    ; TOS = length of horizontal line in pixels
    call line_
    mov ecx, [ v_iconh ]
    shl ecx, 2 ; multiply by 4
    add ecx, 4 ; draw the lower line below the text
    add dword [ v_xy ], ecx ; move the start position down by 4 character heights
    pop ecx
    loop .loop

    mov dword [ v_foregroundColour ], _SCRATCH_
    ret

displayTheKeypad: ; the Keypad is the mnemonic at the bottom right of the display, showing the actions
of each of the 27 keys used
    call setupText_
    mov edi, [ dword currentKeypadIcons ]
    _DUP_
    mov _TOS_, [ keypad_colour ]
    call color
    mov _TOS_, [ vesa_XResolution ] ; was this : mov _TOS_, ( scrnw )
    and _TOS_, 0xFFFF
    sub _TOS_, [ v_nine_iconw ]

```

```

sub _TOS_, 16
mov [ v_leftMargin ], _TOS_      ; x coordinate of left margin of keypad display
mov edx, _TOS_                  ;
add edx, [ v_nine_iconw ]       ; x coordinate of right margin of keypad display
mov [ v_rightMargin ], edx
shl _TOS_, 0x10
mov edx, [ vesa_YResolution ]   ; was this : mov _TOS_, ( scrnw )
and edx, 0x0000FFFF
push _SCRATCH_
mov _SCRATCH_, [ v_keypadY_iconh ]
add _SCRATCH_, 10
sub edx, _SCRATCH_              ; ( ( keypadY * iconh ) + 10 )
add _TOS_, edx

mov [ v_xy ], _TOS_

test byte [ v_quitMode ], 0xFF
jz .forward
pusha
call showEditBox
popa
mov [ v_xy ], _TOS_
.forward:

pop _SCRATCH_
call eight
call eight
call eight
call cr_
; add dword [ v_xy ], ( 4 * iconw * 0x10000 )      ; shift horizontal pixels to the right
mov _SCRATCH_, [ v_iconw ]
shl _SCRATCH_, ( 2 + 16 ); ( 4 * iconw * 0x10000 ) ; shift horizontal pixels to the right
add dword [ v_xy ], _SCRATCH_
mov edi, [ shiftAction ]
add edi, byte 0x0C
mov ecx, 0x03
call four1

call space_
_DUP_
mov _TOS_, [ v_hintChar ]
call emit_

mov dword [ v_leftMargin ], 0x03
mov word [ v_x ], 0x03
call displayTheStack
mov _TOS_, [ vesa_XResolution ] ; was this : mov _TOS_, ( scrnw )
and _TOS_, 0xFFFF
sub _TOS_, [ v_twentytwo_iconw ]
add _TOS_, 3
mov word [ v_x ], ax
lea edi, [ ( history - 4 ) ]    ; the text entered so far
mov ecx, 0x0B
jmp dword four1

; *****
; Tables of keys to return when each of the 24 main keypad positions are pressed
; Note : The keypad key lists below use Shannon-Fano encoded characters
; *****
alphaKeypad:      ; the 'alpha' character keypad keys, the start screen for key entry
    db 'gcr1' ;
    db 'htns' ;
    db 'bmwv' ;
    db 'pyfi' ;
    db 'aoeu' ;
    db 'qkxd' ;

graphicsKeypad:   ; the 'graphics' character keypad icons (Note: not numbers, just characters)
    db '123 ' ;    Note : these are Capital (larger) numbers
    db '4560' ;

```

```

    db '789?' ;
    db '::~!@' ;
    db 'zj.,' ;
    db '*/+-' ;

decimalKeypad:      ; the decimal number entry keypad icons
    db '123 ' ;
    db '4560' ;
    db '789 ' ;
    db '   ' ;
    db '   ' ;
    db '   ' ;

hexadecimalKeypad: ; the hexadecimal number entry keypad icons
    db '123 ' ;
    db '4560' ;
    db '789 ' ;
    db ' abc' ;
    db ' def' ;
    db '   ' ;

; *****
; get keyboard keys
; *****

letter:
    cmp al, 0x04 ; ignore 0 to 3, NOP, N, spacebar, AltGr
    js .forward
    mov edx, [ currentKeypadIcons ]
    mov al, [ _TOS_ + edx ]
.forward:
    ret

key_map_table:      ; map 8042 scan type 1 keycode to colorForth character values
    db 16, 17, 18, 19, 0, 0, 4, 5 ; 0x10 - 0x17
    db 6, 7, 0, 0, 0, 0, 20, 21 ; 0x18 - 0x1F
    db 22, 23, 0, 0, 8, 9, 10, 11 ; 0x20 - 0x27
    db 0, 0, 0, 0, 24, 25, 26, 27 ; 0x28 - 0x2F
    db 0, 1, 12, 13, 14, 15, 0, 0 ; 0x30 - 0x37 N
    db 3, 2 ; 0x38 - 0x39 alt space

; ToDo: add a timeout to the loop
WaitToReceiveKey:      ; Wait until there is byte to receive from the keyboard controller
.back:
    in al, 0x64 ; On-board controller status read
    test al, 1 ; OBF (Output Buffer Full)
    jnz .forward ; exit when bit 0 = 1 the On-board controller has a new character for us
    xor _TOS_, _TOS_
    call pause_ ; not ready yet, so let the other task(s) have a turn
    jmp .back ; jump back and try again
.forward:
;    call pause_ ; not ready yet, so let the other task(s) have a turn
    ret

v_lineOffsetTablePtr:
    dd 0 ; times 16 dd 0

lineOffsetZero:
    mov dword [ v_lineOffset ], 0x00
    ret

lineOffsetPlus:
    add dword [ v_lineOffset ], 0x0C
    ret

lineOffsetMinus:
    sub dword [ v_lineOffset ], 0x0C
    jns .forward
    call lineOffsetZero
.forward:

```

```

ret

; *****
; F1 Help screens
; *****

help0: ; save v_blk , display the first help screen
    _DUP_
    cmp dword [ v_blk ], LAST_BLOCK_NUMBER ; we are displaying the first Help screen
    je .forward
    mov _TOS_, [ v_blk ]
    mov [ v_saved_v_blk ], _TOS_
.forward:
    mov dword [ v_blk ], LAST_BLOCK_NUMBER
    _DROP_
    ret

help1: ; display the second help screen
    mov dword [ v_blk ], ( START_BLOCK_NUMBER + 1 )
    ret

help2: ; display the second third screen
    mov dword [ v_blk ], ( START_BLOCK_NUMBER )
    ret

help3: ; restore the original screen being edited
    _DUP_
    mov _TOS_, [ v_saved_v_blk ]
    mov [ v_blk ], _TOS_
    _DROP_
    ret

HelpTable:
    dd help0
    dd help1
    dd help2
    dd help3

help:
    _DUP_
    mov _TOS_, [ v_help_counter ]
    and _TOS_, 0x03
    call dword [ ( _TOS_ * 4 ) + HelpTable ]
    _DROP_
    inc byte [ v_help_counter ]
    ret

; *****
; Editor
; *****

e_plus:
    call colourBlindModeToggle
    jmp abort_e

abort_e:
    ; call abort
    call c_
abort_e2:
    mov esp, RETURN_STACK_0
    call e_
    ret

executeToken: ; ( -- ) \ action when the QWERT enter key is pressed
    mov byte [ v_quitMode ], 0x00 ; turn off the edit mode orange lines around the keypad
    mov _TOS_, [ v_cad ]
    sub _TOS_, 1 ; step to before the token before the cursor
    shl _TOS_, 2 ; convert cell address to byte address
    mov _TOS_, [ _TOS_ ]
    mov _SCRATCH_, _TOS_

```

```

    and _SCRATCH_, 0x0F          ; check the token type = 3 == red
    cmp _SCRATCH_, 0x03
    je .forward
    cmp _SCRATCH_, 0x0C          ; check the token type = 12 == magenta.  NOT WORKING YET ToDo: fix this
    je .forward
    jmp .forward2
.forward:
    call execute
.forward2:
    _DROP_
    ret

#define FirstFkey (59)          ; F1 = 59

FkeyTable: ; ( c -- a ) \ function key action table
;    dd nul                      ; 57
;    dd nul                      ; 58
    dd help                      ; 59 F1
    dd toggleBase0              ; 60 F2 decimal/hex number display
    dd seeb                     ; 61 F3 show/hide blue words
    dd e_plus                   ; 62 F4 editor
    dd tog_show_ASCII           ; 63 F5 show/hide the ASCII keyboard entry field at the cursor
    dd otherBlock               ; 64 F6 display the previously edited block
    dd nul                      ; 65 F7
    dd nul                      ; 66 F8
    dd toggleBase               ; 67 F9
    dd c_                       ; 68 F10
    dd nul                      ; 69 Num Lock
    dd nul                      ; 70
    dd cursorHome               ; 71 Home
    dd cursorUp                 ; 72 Up arrow
    dd nextBlock                ; 73 PgUp
    dd nul                      ; 74 -
    dd cursorLeft               ; 75 Left arrow
    dd otherBlock               ; 76 display the previously edited block
    dd cursorRight              ; 77 Right arrow
    dd nul                      ; 78 +
    dd cursorEnd                ; 79 End
    dd cursorDown               ; 80 Down arrow
    dd previousBlock            ; 81 PgDn
    dd destack                  ; 82 Insert
    dd deleteAction             ; 83 Delete
    dd nul                      ; 84
    dd nul                      ; 85
    dd nul                      ; 86
    dd toggleBase0              ; 87 F11
    dd nul                      ; 88 F12
    dd executeToken             ; 89 really 121 Enter
    dd abort_e                  ; 90 really 123 Escape

processFkey: ; ( n -- ) \ process the given function key code
;    cmp _TOS_, 121
;    jne .forward1
;    sub _TOS_, ( 121 - 89 )
;.forward1:
    sub _TOS_, FirstFkey        ; convert Fn key value to index from 0
    and _TOS_, 0x1F
    call dword [ ( _TOS_ * 4 ) + FkeyTable ]
;    _DROP_
;    call e_
    ret

get_key_: ; ( -- c ) \ waits for and returns a character from the keyboard, assumes Scan Code Set 1,
set up by the BIOS
    _DUP_
    xor _TOS_, _TOS_
.back:
    ; check if the key is a function key
    cmp _TOS_, FirstFkey        ; F1 key
    js .forward4

```

```

    cmp _TOS_, FirstFkey + 32 ; Fxx key + 1
    jns .forward4
    call processFkey
.forward4:
    _DROP_
    call get_qwerty_key_
;    call WaitToReceiveKey ; Wait until there is a byte to receive from the keyboard controller
;    in al, 0x60 ; read the key value from the Keyboard data port
    mov al, [ v_scanCode ]
;    test al, 0xF0 ; we are only interested in certain key codes (?)
;    jz .back
    cmp al, 0x3A ; exclude keycodes greater than 0x39, cmp is like sub but only affects the
flags
    jnc .back
    mov al, [ key_map_table - 0x10 + EAX ] ; convert to the colorForth value using the 'key_map_table'
table
    ret

; *****
; get qwerty keys
; *****

align 4, db 0 ; fill the gap with 0's

; times 0x40 db 0x00,

qwerty_key_map_table:
;    0 1 2 3 4 5 6 7 8 9 A B C D E F
    db 0x0B, 0x18, 0x02, 0x19, 0x03, 0x1A, 0x04, 0x1B, 0x05, 0x1C, 0x06, 0x1D, 0x07, 0x1E, 0x08, 0x1F ;
0x00
    db 0x09, 0x20, 0x0A, 0x21, 0x1E, 0x05, 0x30, 0x13, 0x2E, 0x0A, 0x20, 0x10, 0x12, 0x04, 0x21, 0x0E ;
0x10
    db 0x22, 0x0D, 0x23, 0x14, 0x17, 0x07, 0x24, 0x22, 0x25, 0x24, 0x26, 0x0C, 0x32, 0x09, 0x31, 0x06 ;
0x20
    db 0x18, 0x03, 0x19, 0x12, 0x10, 0x17, 0x13, 0x01, 0x1F, 0x08, 0x14, 0x02, 0x16, 0x16, 0x2F, 0x11 ;
0x30
    db 0x11, 0x0F, 0x2D, 0x15, 0x15, 0x0B, 0x2C, 0x26, 0x0C, 0x23, 0x34, 0x25, 0x35, 0x27, 0x27, 0x28 ;
0x40
    db 0x28, 0x29, 0x82, 0x2A, 0x8D, 0x2B, 0x83, 0x2C, 0x89, 0x2D, 0x33, 0x2E, 0xB5, 0x2F, 0x39, 0x80 ;
0x50
    db 0x1C, 0x81, 0x0E, 0x82, 0x01, 0x83, 0x3B, 0x84, 0x29, 0x30
; test only
; times 0x40 db 0x00,

get_qwerty_key_: ; get a qwerty key character
    _DUP_
.back:
    call WaitToReceiveKey
    in al, 0x60

    cmp _TOS_, 0x1C ; the Enter key scan code
    jne .forward1
; add _TOS_, ( 89 - 0x1C ) ; convert the code for the Enter key to 89
    mov _TOS_, 89
.forward1:

    cmp _TOS_, 0x81 ; the Escape key scan code
    jne .forward2
    add _TOS_, ( 90 - 0x81 ) ; convert the code for the Escape key to 90
.forward2:

;    cmp _TOS_, 0x03 ; the Left Alt key scan code
;    jne .forward3
;    add _TOS_, 0x02 ; convert the code for the Left Alt key to a space key
; .forward3:

    mov [ v_scanCode ], al
    mov ecx, _TOS_ ; copy keycode into cl
    and cl, 0x7F ; filter out key-up bit 7
    cmp cl, 0x2A ; g?

```

```

    jz .got_c_or_g
    cmp cl, 0x36          ; c?
    jnz .not_c_or_g
.got_c_or_g:
    and al, 0x80          ; extract key-up bit
    xor al, 0x80          ; complement it
    mov [ v_qwerty_key ], _TOS_
    jmp short .back
.not_c_or_g:
    or al, al             ; check if key-up
    js .back              ; if so, try again to get keydown event
    and al, 0x7F          ; filter out key-up bit
    or _TOS_, [ v_qwerty_key ]
    mov edx, qwerty_key_map_table
    mov ecx, 0x35
.back2:
    cmp [edx], al
    jz .forward
    add edx, byte 0x02
    loop .back2
    xor _TOS_, _TOS_
    ret
.forward:
    mov al, [edx+0x01]
    sub edx, qwerty_key_map_table
    shr edx, 1
    mov [ v_digin ], edx
    cmp _TOS_, 59 ; F1 key
;    jnz .forward4
;    ; jmp dword [ _TOS_ * 4 + qwertyActionTable - 0x200 ]
;    xor dword [ current], ((setBase_decimal - $$) ^ (setBase_hex - $$))
;    call toggleBase
;.forward4:
    ret

; *****
; keypad jump tables
; actions for the three editor state change keys : N spacebar AltGr
; *****

graph0:
    dd nul0, nul0, nul0, alph0
    db ' a ' ; _ _ a _ ' a ' ;

graph1:
    dd word0, x, lj, alph
    db 'x.a ' ;

alpha0:
    dd nul0, nul0, number, star0
    db ' 9* ' ;

alpha1:
    dd word0, x, lj, graph
    db 'x.* ' ;

numb0: ; the number keypad before the '-' key has been pressed ???
    dd nul0, minusSign, alphn, toggleBase
    db '-af ' ; 0x23, 0x05, 0x0E, 0x00 ; - a f _ '-af ' ;

numb1: ; the number keypad after the '-' key has been pressed ???
    dd number0, minusSign, endn, toggleBase
    db '-af ' ; 0x15, 0x25, 0x00, 0x00 ; x . _ _ 'x. ' ;

; *****
; Shannon-Fano compression
; *****

bits_:
    db 0x1C

```



```

lj0:
    mov cl, [ bits_ ]
    add cl, 0x04
    shl dword [ esi ],cl
    ret

lj:
    call lj0
    _DROP_
    ret

full:
    call lj0
    inc dword [ v_words ]
    mov byte [ bits_ ], 0x1C
    sub [ bits_ ], ch
    mov _TOS_, edx
    _DUP_
    ret

pack0:
    add _TOS_, byte 0x50
    mov cl, 0x07
    jmp short pack1

pack_:
    cmp al, 0x10
    jnc pack0
    mov cl, 0x04
    test al, 0x08
    jz pack1
    inc ecx
    xor al, 0x18

pack1:
    mov edx, _TOS_
    mov ch,cl

.back:
    cmp [ bits_ ], cl
    jnc .forward
    shr al,1
    jc full
    dec cl
    jmp short .back

.forward:
    shl dword [ esi ],cl
    xor [ esi ], _TOS_
    sub [ bits_ ], cl
    ret

x:
    ; eXit
    call right
    mov _TOS_, [ v_words ]
    lea esi, [ esi + ( _TOS_ * 4 ) ]
    _DROP_
    jmp quit_

word_:
    call right
    mov dword [ v_words ], 0x01
    mov dword [ chars ], 0x01
    _DUP_
    mov dword [ esi ], 0x00
    mov byte [ bits_ ], 0x1C

word1:
    call letter
    jns .forward
    mov edx, [ shiftAction ]
    jmp dword [edx+_TOS_*4]

.forward:

```

```

    test al,al
    jz word0
    _DUP_
    call echo_
    mov al, [ _TOS_ + ASCII_to_SF_table ]
    call pack_
    inc dword [ chars ]
word0:
    _DROP_
    call get_key_
    jmp short word1

; *****
; number display
; *****

digitTable:                                ; convert a keypad key value to a number
    times 0x30 db 0x00                      ;
    db 0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09 ; '0123456789' ; 0x30 to 0x39
    times 0x27 db 0x00
    db 0x0A, 0x0B, 0x0C, 0x0D, 0x0E, 0x0F ; 'abcdef'
    times 0x34 db 0x00

ASCII_to_SF_table:                        ; to convert ASCII value to ShannonFano number
    ; 0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09, 0x0A, 0x0B, 0x0C, 0x0D, 0x0E, 0x0F
    db 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00 ;
0x00
    db 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00 ;
0x10
    db 0x00, 0x2A, 0x00, 0x00, 0x00, 0x00, 0x00, 0x59, 0x00, 0x00, 0x2D, 0x2B, 0x2E, 0x23, 0x25, 0x27 ;
0x20
    db 0x18, 0x19, 0x1A, 0x1B, 0x1C, 0x1D, 0x1E, 0x1F, 0x20, 0x21, 0x29, 0x28, 0x00, 0x00, 0x00, 0x2F ;
0x30
    db 0x2C, 0x35, 0x43, 0x3A, 0x40, 0x34, 0x3E, 0x3D, 0x44, 0x37, 0x52, 0x54, 0x3C, 0x39, 0x36, 0x33 ;
0x40
    db 0x42, 0x47, 0x31, 0x38, 0x32, 0x46, 0x41, 0x3F, 0x45, 0x3B, 0x56, 0x00, 0x00, 0x00, 0x00, 0x53 ;
0x50
    db 0x00, 0x05, 0x13, 0x0A, 0x10, 0x04, 0x0E, 0x0D, 0x14, 0x07, 0x22, 0x24, 0x0C, 0x09, 0x06, 0x03 ;
0x60
    db 0x12, 0x17, 0x01, 0x08, 0x02, 0x16, 0x11, 0x0F, 0x15, 0x0B, 0x26, 0x00, 0x00, 0x00, 0x00, 0x00 ;
0x70

v_sign:                                    ; set to 0xXX when the '-'key is pressed on the keypad
    db 0x00

minusSign:
    ; not byte [ v_sign ]
    mov byte [ v_sign ], '-'
    jmp short number2

number0:
    _DROP_
    jmp short number3

number:
    call [ setCurrentBase ]
    mov byte [ v_sign ], 0x00
    xor _TOS_, _TOS_
number3:
    call get_key_
    call letter
    jns .forward
    mov edx, [ shiftAction ]
    jmp dword [edx+_TOS_*4]
.forward:
    test al,al
    jz number0
    mov al, [ _TOS_ + digitTable ]
    test byte [ v_sign ], '-'
    jz .forward2

```

```

    neg _TOS_
.forward2:
    mov edx, [ esi ]
    imul edx, [ base ]
    add edx, _TOS_
    mov [ esi ], edx
number2:
    _DROP_
    mov dword [ shiftAction ], numb1
    jmp short number3

endn:
    _DROP_
    call [ anumber]
    jmp quit_

setBase_decimal:                ; set the system base to decimal
    mov dword [ base ], 0x0A
    mov dword [ shiftAction ], numb0
    mov dword [ currentKeypadIcons], ( decimalKeypad - 4 )
    ret

setBase_hex:                    ; set the system base to hexadecimal
    mov dword [ base ], 0x10
    mov dword [ shiftAction ], numb0
    mov dword [ currentKeypadIcons], ( hexadecimalKeypad - 4 )
    ret

toggleBase0:
    ; the 'xor's below change the content of 'setCurrentBase_base' and the keypad icon
    xor dword [ setCurrentBase], ((setBase_decimal - $$) ^ (setBase_hex - $$))
    xor byte [ numb0 + 18 ], ( 0x39 ^ 0x66 ) ; 0x39 = '9' , 0x66 = 'f' toggle '9' and 'f' on keypad
display line
    call [ setCurrentBase ]
    ret

toggleBase:
    call toggleBase0
    jmp dword number0

; *****
; text entry
; *****

xn:
    _DROP_
    _DROP_
    jmp quit_

nul0:
    _DROP_
    jmp short quit2

clearHintChar:
    push _TOS_
    xor _TOS_, _TOS_
    mov byte [ v_hintChar ], 0x00 ; clear the hint character
    pop _TOS_
    ret

quit_:
    ; get a word from keypad and interpret it
    mov dword [ shiftAction ], alpha0
    lea edi, [ alphaKeypad - 4]
quit1:
    mov [ dword currentKeypadIcons ], edi
quit2:
    test dword [ x_qwerty ], 0xFFFFFFFF
    jz .forward
    jmp dword [ x_qwerty ] ; jump to the address in x_qwerty if it is non-zero
.forward:

```

```

    call get_key_                ; calls pause_ while waiting for a character
    cmp al, 0x04                 ;
    jns .forward2
    mov edx, [ shiftAction ]
    jmp dword [ edx + _TOS_ * 4 ] ; alpha0 jump table element
.forward2:
    add dword [ shiftAction ], byte +0x14
    call word_
    call [ aword ]
    jmp short quit_              ; endless loop

alpn:
    _DROP_

alph0:
    mov dword [ shiftAction ], alpha0
    lea edi, [ alphaKeypad - 4 ]
    jmp short Xstar0

star0:
    mov dword [ shiftAction ], graph0
    lea edi, [ ( graphicsKeypad - 4 ) ]
Xstar0:
    _DROP_
    jmp short quit1

alph:
    mov dword [ shiftAction ], alpha1
    lea edi, [ alphaKeypad - 4 ]
    jmp short Xgraph

graph:
    mov dword [ shiftAction ], graph1
    lea edi, [ ( graphicsKeypad - 4 ) ]
Xgraph:
    mov [ currentKeypadIcons ], edi
    jmp dword word0

; Note: defining drawTheCursor as a sub-routine and calling it produces a strange bug :
; moving left 24 times using the left arrow key, from the end of the block, crashes the editor.
; I suspect that the use of the stack to store (and later replace) deleted tokens gets confused
; if a call to drawTheCursor happens occasionally...
; This code should be re-worked. It is just too delicate...
; drawTheCursor:
;     mov [ v_cad ], edi
;     push _SCRATCH_
;     mov _SCRATCH_, [ v_10000_iconw ]
;     sub dword [ v_xy ], _SCRATCH_ ; move one icon's worth of horizontal pixels to the left
;     _DUP_
;     mov _SCRATCH_, [ v_foregroundColour ] ; save the current colour
;     mov _TOS_, colour_PacMan ; for the "PacMan" cursor
;     call color
;     mov _TOS_, 0x04 ; display the "PacMan" cursor
;     mov cx, [ v_x ]
;     cmp cx, [ v_rightMargin ]
;     js .forward5
;     ; the cursor is too far to the right on the screen
;     call emit_
;     mov [ v_10000_iconw ], _SCRATCH_
;     sub dword [ v_xy ], _SCRATCH_ ; move one icon's worth of horizontal pixels to the left
;     jmp .forward6
; .forward5:
;     ; the cursor can be drawn
;     call emit_
; .forward6:
;     call doShowASCII ; optionally show the ASCII entry field
;     mov dword [ v_foregroundColour ], _SCRATCH_ ; restore the current colour
;     pop _SCRATCH_
;     ret

```

```

; *****
; Shannon-Fano decompression and display
; *****

unpack:      ; ( token -- token' nextCharacter )
  _DUP_      ; copy TOS to our data stack SOS
  test _TOS_, _TOS_
  js .forward
  shl dword [ esi ], 0x04
  rol _TOS_, 0x04
  and _TOS_, byte 0x07
  ret
.forward:
  shl _TOS_, 1
  js .forward2
  shl dword [ esi ], 0x05
  rol _TOS_, 0x04
  and _TOS_, byte 0x07
  xor al, 0x08
  ret
.forward2:
  shl dword [ esi ], 0x07
  rol _TOS_, 0x06
  and _TOS_, byte 0x3F
  sub al, 0x10
  ret

qrng: ; ( a cursor -- a' ) edi contains pointer to current address to display
  _DUP_
  inc dword [ esi ]
  cmp [ v_curs ], edi
  jnz .forward          ; address to display = cursor address?
  mov [ v_curs ], _TOS_  ; yes,
.forward:
  cmp _TOS_, [ v_curs ]  ; time to draw the cursor?
  jz .forward2
  jns .forward4          ; time to draw the cursor?
  mov [ v_pcad ], edi    ; no, so exit
.forward4:
  _DROP_
  ret                    ; exit here

.forward2:
  ; call drawTheCursor ; Note: do not do this!!! See notes for drawTheCursor:
  mov [ v_cad ], edi
  push _SCRATCH_
  mov _SCRATCH_, [ v_10000_iconw ]
  sub dword [ v_xy ], _SCRATCH_ ; move one icon's worth of horizontal pixels to the left
  _DUP_
  mov _SCRATCH_, [ v_foregroundColour ] ; save the current colour
  mov _TOS_, colour_PacMan
  call color
  mov _TOS_, 0x04 ; display the "PacMan" cursor
  mov cx, [ v_x ]
  cmp cx, [ v_rightMargin ]
  js .forward5
  call emit_
  mov _SCRATCH_, [ v_10000_iconw ]
  sub dword [ v_xy ], _SCRATCH_ ; move one icon's worth of horizontal pixels to the left
  jmp .forward6
.forward5:
  call emit_
.forward6:
  mov dword [ v_foregroundColour ], _SCRATCH_ ; restore the current colour
  pop _SCRATCH_
  ret
  ret

; *****
; Conventional Forth display (does not require colours)

```

```

; *****

currentState:
    dd 0

lastState:
    dd 0

txt0:
    call white
    EMIT_IMM('(')
    call space_
    ret

txt1:
    call white
    EMIT_IMM(')')
    call space_
    ret

imm0:
    call yellow
    EMIT_IMM('[')
    call space_
    ret

imm1:
    call yellow
    EMIT_IMM(']')
    call space_
    ret

mvar0:
    call yellow
    EMIT_IMM('[')
    call space_
    EMIT_IMM('m')
    EMIT_IMM('v')
    EMIT_IMM('a')
    EMIT_IMM('r')
    call space_
    ret

mvar1:
    call yellow
    EMIT_IMM(']')
    call space_
    ret

; unfortunately we need to display the ':' after the CR, so must do this in redWord , not here
; colon0:
;     call red
;     EMIT_IMM(':')
;     call space_
;     ret
;
;     dd nul, imm0, nul, colon0, nul, nul, nul, nul, nul, txt0, nul, nul, mvar0, nul, nul, nul

txts:
    db 0, 1, 1, 3, 4, 5, 6, 7, 1, 9, 9, 9, 12, 13, 14, 15

tx:
    ; ( c -- c ) \ return the value in the given offset in txts
    and _TOS_, 0xFF
    mov _TOS_, [ _TOS_ + txts ]
    and _TOS_, 0xFF
    ret

newActions:
    dd nul, imm0, nul, nul, nul, nul, nul, nul, nul, txt0, nul, nul, mvar0, nul, nul, nul

```

```

dotNew:      ; ( state -- )
             call [ ( _TOS_ * 4 ) + newActions ]
             ret

oldActions:
             dd nul, imm1, nul, nul, nul, nul, nul, nul, txt1, nul, nul, mvar1, nul, nul, nul

dotOld:      ; ( state -- )
             call [ ( _TOS_ * 4 ) + oldActions ]
             ret

colourBlindAction: ; ( state -- state ) \ perform the required action on change of state
             push _SCRATCH_
             _DUP_
             call tx
             cmp _TOS_, 0x00
             jz .end ; no action on extension tokens, value 0
             mov _SCRATCH_, [ currentState ]
             mov [ currentState ], _TOS_
             cmp _SCRATCH_, [ currentState ] ; compare the new state on TOS to the last one saved in
             currentState
             jz .end ; exit if there has been no change of state
             _DUP_
             mov _TOS_, _SCRATCH_
             call dotOld ;
             mov _TOS_, [ currentState ]
             call dotNew
             _DROP_
             cmp byte [ currentState ], 0x0000
             jz .end
             mov _SCRATCH_, [ currentState ]
             mov [ lastState ], _SCRATCH_
             .end:
             _DROP_
             pop _SCRATCH_
             ret

; \ Block 70
; ( Colourblind Editor Display )
; #1 MagentaV currentState $01 MagentaV lastState
; : +txt white $6D emit space ;
; : -txt white $6E emit space ;
; : +imm yellow $58 emit space ;
; : -imm yellow $59 emit space ;
; : +mvar yellow $09 emit $11 emit $05 emit $01 emit space ;
; : txs string $03010100 , $07060504 , $09090901 , $0F0E0D0C , ( ; )
; : tx ( c-c ) $0F and txs + 1@ $0F and ;
; : .new currentState @ $0F and jump nul +imm nul nul nul nul nul nul +txt nul nul +mvar nul nul nul ;
; : .old lastState @ $0F and jump nul -imm nul nul nul nul nul nul -txt nul nul nul nul nul ;
; here
; : cb ( n-n ) #0 + 0if ; then tx
;   currentState @ swap dup currentState ! - drop if .old .new
;   currentState @ #0 + if dup lastState ! then then ;
; : cbs ( -- here ) #0 + $00 + cblind ! ;

; colourBlind:      ; ( state -- state ) \ vectored colorForth to display colourBlind extra characters (
e.g. ':' for red words )
;   call dword [ x_colourBlind ]
;   ret

; *****
; Show an ASCII editable entry field at the cursor
; *****

ShowASCIIAction:    ; ( -- )
;   call white
;   call space_
;   EMIT_IMM('U')
;   EMIT_IMM('U')
;   EMIT_IMM('U')

```

```

    EMIT_IMM('U')
    call space_
    ret
    ret

; *****
; *****

lowercase:    ; display a white text word in normal lower-case letters
    call white
showSF_EDI_:  ; ( -- ) \ display a Shanon-Fano encoded token pointed to by edi in the current colour
    _DUP_
    mov _TOS_, [ ( edi * 4 ) - 0x04 ] ; fetch the next token - drops through to showShannonFano

showShannonFano:    ; ( token -- ) \ display the Shannon-Fano encoded token on TOS
    ; ASCII / UTF8 support. If the first Shannon-Fano encoded letter is a 4 bit NULL,
    ; display the next 24 bits as three ASCII characters.
    mov _SCRATCH_, _TOS_ ; save the token value
    and _SCRATCH_, 0xF0000000
    cmp _SCRATCH_, 0x00000000
    jnz .forward
    ; display as three ASCII characters
    mov _SCRATCH_, _TOS_

    mov _TOS_, _SCRATCH_
    shr _TOS_, 20
    and _TOS_, 0x000000FF
    jz .null_terminator
    _DUP_
    call emit_

    mov _TOS_, _SCRATCH_
    shr _TOS_, 12
    and _TOS_, 0x000000FF
    jz .null_terminator
    _DUP_
    call emit_

    mov _TOS_, _SCRATCH_
    shr _TOS_, 4
    and _TOS_, 0x000000FF
    jz .null_terminator
    _DUP_
    call emit_

    ; arrive here if an ASCII character is an ASCII NULL, or if all three have been emitted
.null_terminator:
    call space_ ; display a space character at the end of the word
    _DROP_
    ret

.forward:

; display as Shannon-Fano encoded token name
and _TOS_, byte -0x10 ; and _TOS_, 0xFFFFFFFF0 ignore the token colour when displaying the letters

lowercasePrimitive: ; ( token -- ) \ display the given Shanon-Fano encoded word in the current colour
    call unpack
    jz lowercasePrimitiveEnd
    call emitSF_
    jmp lowercasePrimitive
lowercasePrimitiveEnd:
    call space_
    _DROP_
    _DROP_
    ret

typeName32tok:    ; ( token -- ) \ display the given Shanon-Fano encoded word as a number in the
current colour
    _DROP_ ; call dotHex8_

```



```

    mov dword [ lastTokenWasLiteral ], 0xFFFFFFFF
    ret

typeNumber32:    ; ( token -- ) \ display the given Shanon-Fano encoded word as a hex number in the
current colour
    call dotHex8_
    mov dword [ lastTokenWasLiteral ], 0x00000000
    ret

typeNumber27:    ; ( token -- ) \ display the given Shanon-Fano encoded word as a 27 bit hex number in
the current colour
    shr _TOS_, 5
    call dotHex
    ret

lastTokenWasLiteral:
    dd 0x00

lastShannonFanoToken:
    dd 0x00

magentaPrimitive: ; ( token -- )
    call showShannonFano
    mov dword [ lastTokenWasLiteral ], 0xFFFFFFFF
    ret

displayOneShannonFanoActions: ; * = number
    dd showShannonFano        ; 0    extension token, remove space from previous word, do not change
the colour
    dd showShannonFano        ; 1    yellow "immediate" word
    dd typeNumber32tok        ; 2    * yellow "immediate" 32 bit number in the following pre-parsed cell
    dd showShannonFano        ; 3    red forth wordlist "colon" word
    dd showShannonFano        ; 4    green compiled word
    dd typeNumber32tok        ; 5    * green compiled 32 bit number in the following pre-parsed cell
    dd typeNumber27          ; 6    * green compiled 27 bit number in the high bits of the token
    dd showShannonFano        ; 7    cyan macro wordlist "colon" word
    dd typeNumber27          ; 8    * yellow "immediate" 27 bit number in the high bits of the token
    dd showShannonFano        ; 9    white lower-case comment
    dd camelcasePrimitive     ; A    first letter capital comment
    dd uppercasePrimitive     ; B    white upper-case comment
    dd magentaPrimitive       ; C    magenta variable
    dd showShannonFano        ; D
    dd showShannonFano        ; E    editor formatting commands
    dd showShannonFano        ; F

times 0x20 db 0x55
testme:
    dd 0x75240CFF ; 0xFF, 0x0C, 0x24, 0x75
    dd 0x123456
    ret
times 0x20 db 0x77

leave_:    ; terminate a for ... next loop
    mov dword [ esp + 4 ], 0x01
    ret

dotsf_:    ; ( token -- ) \ display the given Shannon-Fano encoded word in the token's colour
    push edi
    mov edx, _TOS_
    and _TOS_, 0xFFFFFFFF0
    _DUP_
    mov edi, [ lastTokenWasLiteral ]
    test edi, 0x00000000
    jz .forward3
    mov edx, 0
.forward3:
    and edx, byte 0x0F
    jnz .forward    ; do not change the colour if this is an extension token
    ; this is an extension token
    mov edx, [ lastShannonFanoToken ]

```

```

        ; if the colour is Camelcase 0x0A, make it lowercase 0x09
        ; e.g. Interrupt would be shown as InterrUpt if the extension token is displayed with an initial
Capital
        mov _SCRATCH_, edx
        and _SCRATCH_, 0x0F      ; just the colour
        sub _SCRATCH_, 0x0A
        jne .forward4
        and edx, 0xFFFFFFFF      ; remove the colour
        or edx, 0x00000009       ; make it lowercase
        .forward4:
        mov _SCRATCH_, [ v_10000_iconw ]
        sub dword [ v_xy ], _SCRATCH_ ; move iconw horizontal pixels back, to remove the space at the
end of the last word
        jmp .forward2
        .forward:
        ; this is not an extension token
        mov [ lastShannonFanoToken ], edx
        .forward2:
        push _TOS_
        mov _TOS_, [ ( edx * 4 ) + actionColourTable ]
        call color
        pop _TOS_
        call [ ( edx * 4 ) + displayOneShannonFanoActions ]
        pop edi
        ret

redWord:      ; display a red word
        mov cx, [ v_x ]
        cmp cx, [ v_leftMargin ]
        jz .forward      ; do not do a cr if we are already at the left margin
        mov cl, [ v_not_cr ]
        cmp cl, 0
        jnz .forward      ; do not do a cr if it has been disabled by a blue -cr token
        call cr_
        .forward:
        mov byte [ v_not_cr ], 0
        call setRed

        cmp byte [ v_colourBlindMode ], 0x00
        jz .forward2
        test byte [ v_blk ], 0x01      ; do not display colourblind characters in odd numbered shadow blocks
        jnz .forward2
        EMIT_IMM(':')      ; emit a ':' if in colourblind mode
        call space_
        .forward2:
        jmp showSF_EDI_

greenWord:    ; display a green word
        call setGreen
        jmp showSF_EDI_

cyanWord:     ; display a cyan word
        call setCyan
        jmp showSF_EDI_

yellowWord:   ; display a yellow word
        call yellow
        jmp showSF_EDI_

; Note : Camelcase tokens do not support ASCII output
camelcase:    ; display a white word with the first letter Capitalised
        call white
        _DUP_
        mov _TOS_, [ ( edi * 4 ) - 0x04 ]
        and _TOS_, byte -0x10
camelcasePrimitive:
        call unpack
        add al, 0x30      ; make the first character upper case
        call emitSF_      ; display it
camelcasePrimitive_2:    ; display the rest of the word

```

```

    call unpack
    jz lowercasePrimitiveEnd
    call emitSF_
    jmp camelcasePrimitive_2

; Note : UPPERCASE tokens do not support ASCII output
uppercase:    ; display a white word with all letters CAPITALISED
    call white
    _DUP_
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    and _TOS_, byte -0x10
uppercasePrimitive:
    call unpack
    jz lowercasePrimitiveEnd
    add al, 0x30
    call emitSF_
    jmp uppercasePrimitive

extension:    ; display an extension token, do not change the colour
    mov _SCRATCH_, [ v_10000_iconw ]
    sub dword [ v_xy ], _SCRATCH_    ; move iconw horizontal pixels back, to remove the space at the end of
the last word
    test dword [ ( edi * 4 ) - 0x04 ], 0xFFFFFFFF0
    jnz showSF_EDI_
    dec edi
    mov [ v_lcad ], edi
    call space_
    call qring
    pop edx                                ; EXIT from calling word
    _DROP_                                ; the ret below will return to the word that called extension
    ret                                    ; so it looks like it never happened

greenShortNumber:    ; display the green compiled 27 bit number in the high bits of the token
    mov edx, [ ( edi * 4 ) - 0x04 ]
    sar edx, 0x05
    jmp short greenNumber1

magentaVariable:    ; display a magenta variable using the 32 bit number in the following pre-parsed cell
    mov dword [ x_numberDisplay ], dotDecimal
    cmp dword [ base ], byte 0x0A    ; check the current BASE value ( 10 or 16 for decimal or hex)
    jz .forward
    mov dword [ x_numberDisplay ], dotHex
.forward:
    call setMagenta
    call showSF_EDI_                ; display the name of the variable
    mov edx, [ ( edi * 4 ) + 0x00 ]    ; load the value of the variable from the pre-parsed source
    inc edi                        ; step over the variable value in the pre-parsed source
    call setMagentaData
    jmp short displayNumber

greenNumber:    ; display the value of a hexadecimal/decimal number in green
    mov edx, [ ( edi * 4 ) + 0x00 ]    ; load the value of the variable from the pre-parsed source
    inc edi                        ; step over the variable value in the pre-parsed source
greenNumber1:
    call green
    jmp short displayNumber

yellowShortNumber:
    mov edx, [ ( edi * 4 ) - 0x04 ] ; load the value of the number from the current token in the pre-
parsed source
    sar edx, 0x05                ; remove the token colour bits
    jmp short yellowNumber1

yellowNumber:    ; ( -- ) display a number word, constant value following in the pre-parsed source
    mov edx, [ ( edi * 4 ) + 0x00 ]    ; load the value of the number from the pre-parsed source
    inc edi                        ; step over the number value in the pre-parsed source
yellowNumber1:    ; ( -- ) display a yellow number word
    call yellow
displayNumber:    ; ( rgb -- ) display the number in edx with the given colour, using the base implied in
x_numberDisplay

```

```

    _DUP_
    mov _TOS_, edx
    ; jmp qdot
    jmp dword [ x_numberDisplay ]

; *****
; Blue words - formatting the editor display
; *****

get_x:  ; ( -- c ) \ return the current x character position
    push edx
    _DUP_
    xor _TOS_, _TOS_
    mov ax, word [ v_x ]
    xor edx, edx                ; clear high 32 bits of dividend
    div dword [ v_iconw ]      ; EDX:EAX divided by the icon width , EAX now contains the current
    ; character position, EDX the remainder
    pop edx
    ret

set_x:  ; ( c -- ) \ set the current x character position
    push edx
    xor edx, edx
    mul dword [ v_iconw ]
    mov word [ v_x ], ax
    pop edx
    _DROP_
    ret

#define TAB_SIZE 24

tab:    ; ( -- ) \ align to the next n character column
;    _DUP_
    pusha
    call get_x
    xor edx, edx                ; clear high 32 bits of dividend
    mov _SCRATCH_, TAB_SIZE
    div _SCRATCH_
    mul _SCRATCH_
    add _TOS_, TAB_SIZE
    call set_x
    popa
    ret

tab3:
    pusha
    call get_x
    xor edx, edx                ; clear high 32 bits of dividend
    mov _SCRATCH_, 0x03
    div _SCRATCH_
    mul _SCRATCH_
    add _TOS_, 0x03
    call set_x
    popa
    ret

not_cr:
    not byte [ v_not_cr ]
    ret

blueWord:  ; ( -- ) \ format the editor display screen using certain blue tokens
    _DUP_
    mov al, [ v_seeb ]
    cmp al, 0
    jz .forward
    call setBlue
    call showSF_EDI_
.forward:
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    cmp _TOS_, 0x9080000E ; cr

```

```

        jnz .skip1
        call cr_
.skip1:
        cmp _TOS_, 0xE64B8C0E ; -tab
        jnz .skip2
        call not_cr
        call tab
.skip2:
        cmp _TOS_, 0x25C6000E ; tab
        jnz .skip3
        call tab
.skip3:
        cmp _TOS_, 0xC620000E ; br
        jnz .skip4
        call cr_
        call cr_
.skip4:
        cmp _TOS_, 0xE721000E ; -cr
        jnz .skip5
        call not_cr
.skip5:
        cmp _TOS_, 0x90FB000E ; cr+   cr and 3 spaces
        jnz .skip6
        call cr_
        call space_
        call space_
        call space_
.skip6:
        cmp _TOS_, 0x25C7AC0E ; tab3   align to next 3 space column
        jnz .skip7
        call tab3
.skip7:
        cmp _TOS_, 0xEA00000E ; .
        jnz .skip8
        call space_
.skip8:
        cmp _TOS_, 0xEBD4000E ; ..
        jnz .skip9
        call space_
        call space_
.skip9:
        cmp _TOS_, 0xEBD7A80E ; ...
        jnz .skip10
        call space_
        call space_
        call space_
.skip10:
        cmp _TOS_, 0xEBD7AF5E ; ....
        jnz .skip11
        call space_
        call space_
        call space_
        call space_
.skip11:
        _DROP_
        ret

; silverWord:   ; ( -- )   ; ToDo: document this
;   mov edx, [ ( edi * 4 ) - 0x04 ] ; load the value of the action from the current token in the pre-
parsed source
;   sar edx, 0x05                ; remove the token colour bits
;   _DUP_
;   mov _TOS_, colour_white
;   cmp dword [ x_numberDisplay ], dotDecimal
;   jz .forward
;   mov _TOS_, colour_silver
; .forward:
;   jmp short displayNumber
;   ret

```

```

silverWord:      ; display a silver word
    call setSilver
    jmp showSF_EDI_

displayShannonFanoActions: ; * = number
    dd extension      ; 0      extension token, remove space from previous word, do not change the
colour
    dd yellowWord      ; 1      yellow "immediate" word
    dd yellowNumber    ; 2      * yellow "immediate" 32 bit number in the following pre-parsed cell
    dd redWord         ; 3      red forth wordlist "colon" word
    dd greenWord       ; 4      green compiled word
    dd greenNumber     ; 5      * green compiled 32 bit number in the following pre-parsed cell
    dd greenShortNumber ; 6      * green compiled 27 bit number in the high bits of the token
    dd cyanWord        ; 7      cyan macro wordlist "colon" word
    dd yellowShortNumber ; 8      * yellow "immediate" 27 bit number in the high bits of the token
    dd lowercase       ; 9      white lower-case comment
    dd camelcase       ; A      first letter capital comment
    dd uppercase       ; B      white upper-case comment
    dd magentaVariable ; C      magenta variable
    dd silverWord      ; D
    dd blueWord        ; E      editor formatting commands
    dd nul             ; F

v_lineOffset:
    dd 1      ; the top line of the display

doColourBlind: ; ( state -- ) \ add conventional Forth punctuation based on the new and last states
    cmp byte [ v_colourBlindMode ], 0x00
    jz .forward3
    test byte [ v_blk ], 0x01      ; do not display colourblind characters in odd numbered shadow blocks
    jnz .forward3
    call dword colourBlindAction    ; pass the new state to colourBlind so that extra characters can be
added to the display
    .forward3:
    _DROP_
    ret

doShowASCII: ;
    cmp byte [ v_show_ASCII ], 0x00
    jz .forward4

    call dword ShowASCIIAction      ; pass the new state to colourBlind so that extra characters can be
added to the display
    .forward4:
    ret

plusList: ; ( -- ) display the current colorForth block
    _DUP_
    xor _TOS_, _TOS_
    mov [ currentState ], _TOS_
    mov [ lastState ], _TOS_
    _DROP_

    call setupText_      ; setup the clip window for this display
    _DUP_
    mov _TOS_, [ v_lcad ]
    mov [ v_cad ], _TOS_
    mov _TOS_, [ v_blk ]      ; get the current block number to be edited
    call blockToCellAddress    ; add the RELOCATED block number offset and convert to cell address
    mov edi, _TOS_
    xor _TOS_, _TOS_
    add edi, [ v_lineOffset ]
    mov [ v_pcad ], edi

.back:
    mov edx, dword [ ( edi * 4 ) + 0x00 ] ; edi is the display pointer and is a cell address
    call qring      ; show one Shannon-Fano encoded word pointed to by edi
    inc edi
    ; adjust the number base according to bit 5 of the token value, only used by number display words
    mov dword [ x_numberDisplay ], dotDecimal
    test dl, 0x10

```

```

    jz .forward2
    mov dword [ x_numberDisplay ], dotHex
.forward2:
    and edx, byte 0x0F
    _DUP_
    mov _TOS_, edx
    call doColourBlind
    call [ ( edx * 4 ) + displayShannonFanoActions ]
    jmp short .back

refresh:
    ; refresh the editor display
    call show
    ; set the screen task to execute the code following :
    call page_
    ; cleat the screen
    call displayBlockNumber
    ; display the current block number on the screen
    call plusList
    ; list the contents of the block
    _DUP_
    mov _TOS_, 0x0F
    call doColourBlind
    ; display the final colourblind punctuation, set up for next call of
plusList
    jmp dword displayTheKeypad

align 4, db 0 ; fill the gap with 0's

actionColourTable:
    ; * = number
    dd colour_orange ; 0 extension token, remove space from previous word, do not change the
colour
    dd colour_yellow ; 1 yellow "immediate" word
    dd colour_yellow ; 2 * yellow "immediate" 32 bit number in the following pre-parsed cell
    dd colour_red ; 3 red forth wordlist "colon" word
    dd colour_green ; 4 green compiled word
    dd colour_green ; 5 * green compiled 32 bit number in the following pre-parsed cell
    dd colour_green ; 6 * green compiled 27 bit number in the high bits of the token
    dd colour_cyan ; 7 cyan macro wordlist "colon" word
    dd colour_yellow ; 8 * yellow "immediate" 27 bit number in the high bits of the token
    dd colour_white ; 9 white lower-case comment
    dd colour_white ; A first letter capital comment
    dd colour_white ; B white upper-case comment
    dd colour_magenta ; C magenta variable
    dd colour_silver ; D
    dd colour_blue ; E editor formatting commands
    dd colour_black ; F

vector:
    dd 0 ; pointer to call table for keypad ( see keypd )

action:
    db 1

align 4, db 0 ; fill the gap with 0's

cursorLeft:
    ; ( -- )
    dec dword [ v_curs ]
    jns .forward
    inc dword [ v_curs ]
    .forward:
    ret

limitToEndOfBlock:
    call countTokens
    cmp _TOS_, dword [ v_curs ]
    jns .forward
    mov dword [ v_curs ], _TOS_
    .forward:
    _DROP_
    ret

cursorRight:
    inc dword [ v_curs ]
    call limitToEndOfBlock
    ret

```

```

countAllTokens:      ; ( -- x ) \ counts red and magenta tokens and all tokens in the current block
    _DUP_
    xor _TOS_, _TOS_
    mov dword [ v_numberOfMagentas ], _TOS_
    mov dword [ v_numberOfRedAndMagentas ], _TOS_ ; count up Red and Magenta tokens
    mov dword [ v_numberOfTokens ], _TOS_ ; count all tokens
    mov dword [ v_numberOfBigConstants ], _TOS_ ; count of 32 bit literal tokens

    mov ecx, 0x00100 ; 256 x 4 byte cells = 1 block
.loop:

    _DUP_
    mov _TOS_, [ v_numberOfTokens ]
    call nth_to_token
    mov _SCRATCH_, _TOS_
    _DROP_
    cmp _SCRATCH_, 0x00
    je .forward ; exit if the token value is 0, means end of block

    inc dword [ v_numberOfTokens ]

    and _SCRATCH_, 0x0F ; look at the token type

    cmp _SCRATCH_, 0x03 ; red token
    jne .forwardRed
    inc dword [ v_numberOfRedAndMagentas ]
.forwardRed:

    cmp _SCRATCH_, 0x0C ; magenta token
    jne .forwardMagenta
    inc dword [ v_numberOfRedAndMagentas ]
    inc dword [ v_numberOfMagentas ] ; correction for magenta variables
    inc dword [ v_numberOfTokens ] ; step over the Magenta variable data cell
.forwardMagenta:

    cmp _SCRATCH_, 0x02 ; yellow 32 bit literal
    jne .forwardBig
    inc dword [ v_numberOfBigConstants ] ; correction for literal constants
    inc dword [ v_numberOfTokens ] ; step over the data cell
.forwardBig:

    cmp _SCRATCH_, 0x05 ; green 32 bit literal
    jne .forwardBig2
    inc dword [ v_numberOfBigConstants ] ; correction for literal constants
    inc dword [ v_numberOfTokens ] ; step over the data cell
.forwardBig2:

    loop .loop
.forward: ; found the end of the block
; mov _TOS_, dword [ v_numberOfRedAndMagentas ]
ret

countRedAndMagentaTokens: ; ( -- n ) \ counts red and magenta tokens in the current block
    call countAllTokens
    mov _TOS_, dword [ v_numberOfRedAndMagentas ]
    ret

countTokens: ; ( -- n ) \ counts all tokens up to the end of the current block
    call countAllTokens
    mov _TOS_, dword [ v_numberOfTokens ]
    sub _TOS_, dword [ v_numberOfMagentas ]
    sub _TOS_, dword [ v_numberOfBigConstants ]
    and _TOS_, 0x00003FFF ; limit the maximum number of tokens, just in case
    ret

; *****

cursorDownToNth: ; ( -- ) \ step down to after the v_cursLine'th red or magenta token
    _DUP_

```



```

xor _TOS_, _TOS_
mov dword [ v_numberOfMagentas ], _TOS_
mov dword [ v_curs ], _TOS_
mov dword [ v_numberOfBigConstants ], _TOS_

mov dword _TOS_, [ v_cursLine ]
mov dword [ v_curs_number_down ], _TOS_

mov ecx, 0x00100      ; 256 x 4 byte cells = 1 block
.loop:

cmp dword [ v_curs_number_down ], 0x00 ; test for zero
je .forward          ; jump to the end if v_curs_number_down reaches zero

_DUP_
mov _TOS_, [ v_curs ]
call nth_to_token
mov _SCRATCH_, _TOS_
_DROP_
cmp _SCRATCH_, 0x00
je .endOfBlock       ; exit if the token value is 0, means end of block

inc dword [ v_curs ]

and _SCRATCH_, 0x0F   ; look at the token type

cmp _SCRATCH_, 0x03   ; red token
jne .forwardRed
dec dword [ v_curs_number_down ]
.forwardRed:

cmp _SCRATCH_, 0x0C   ; magenta token
jne .forwardMagenta
dec dword [ v_curs_number_down ]
inc dword [ v_numberOfMagentas ] ; correction for magenta variables
inc dword [ v_curs ]          ; step over the Magenta variable data cell
.forwardMagenta:

cmp _SCRATCH_, 0x02   ; yellow 32 bit literal
je .forwardBig

cmp _SCRATCH_, 0x05   ; green 32 bit literal
jne .forwardBig2
.forwardBig:
inc dword [ v_numberOfBigConstants ] ; correction for literal constants
inc dword [ v_curs ]                ; step over the data cell
.forwardBig2:

loop .loop
.forward:          ; found the right number of red or magenta tokens, so exit
mov _SCRATCH_, dword [ v_numberOfMagentas ]
add _SCRATCH_, dword [ v_numberOfBigConstants ]
sub dword [ v_curs ], _SCRATCH_ ; the correction for magenta variables
.endOfBlock:
call limitToEndOfBlock
_DROP_
ret

cursorUp:      ; ( -- ) \ step down to after the next red token, or after 0x16 steps, or until the end of
the block
dec dword [ v_cursLine ]
jnz .forward
mov dword [ v_cursLine ], 0x00
.forward:
; mov dword [ v_cursLine ], 0x03
call cursorDownToNth
ret

cursorDown:    ; ( -- ) \ step down to after the next red token, or after 0x16 steps, or until the end of
the block

```

```

    inc dword [ v_cursLine ]
    call countRedAndMagentaTokens
    inc dword _TOS_ ; add one so that we can go past the last token to the end of the block
    cmp dword [ v_cursLine ], _TOS_
    js .forward
    mov dword [ v_cursLine ], _TOS_
.forward:
    _DROP_
;   mov dword [ v_cursLine ], 0x02
    call cursorDownToNth
    ret

cursorEnd:    ; ( -- )
    call countRedAndMagentaTokens
    inc dword _TOS_ ; add one so that we can go past the last token to the end of the block
    mov dword [ v_cursLine ], _TOS_
    _DROP_
    call cursorDownToNth
    call limitToEndOfBlock
    ret

cursorHome:   ; ( -- )
    xor _SCRATCH_, _SCRATCH_
    mov dword [ v_numberOfMagentas ], _SCRATCH_
    mov dword [ v_curs ], _SCRATCH_ ; the graphics cursor for drawing the block
    mov dword [ v_lineOffset ], _SCRATCH_ ; the cursor position to start drawing the block
    mov dword [ v_lineOffsetTablePtr ], _SCRATCH_ ; a pointer to the cursor for each line in the display
    mov dword [ v_numberOfMagentas ], _SCRATCH_ ; count of Magenta variables displayed so far in the
edited block
    mov dword [ v_cursLine ], _SCRATCH_
    ret

nextBlock:    ; ( -- )
    add dword [ v_blk ], byte 0x02
    call lineOffsetZero
    ret

previousBlock:
    cmp dword [ v_blk ], byte ( START_BLOCK_NUMBER + 2 )
    js .forward
    sub dword [ v_blk ], byte 0x02
.forward:
    call lineOffsetZero
    ret

otherBlock:
    mov ecx, [ v_blk ]
    xchg ecx, [ v_otherBlock ]
    mov [ v_blk ], ecx
    ret

tog_show_ASCII:
    not byte [ v_show_ASCII ]
    ret

shadow:       ; alternate between source and shadow blocks
    xor dword [ v_blk ], byte 0x01
    ret

insert0:      ; ( ... -- )
    mov ecx, [ v_lcad ]
    add ecx, [ v_words ]
    xor ecx, [ v_lcad ]
    and ecx, 0xFFFFF00
    jz insert1
    mov ecx, [ v_words ]
.back:
    _DROP_
    loop .back
    ret

```

```

insert1:
    push esi
    mov esi, [ v_lcad ]
    mov ecx, esi
    dec esi
    mov edi, esi
    add edi, [ v_words ]
    shl edi, 0x02
    sub ecx, [ v_cad ]
    js .forward
    shl esi, 0x02
    std
    rep movsd                ; copy ecx 32 bit words from ds:esi to es:edi
    cld
.forward:
    pop esi
    shr edi, 0x02
    inc edi
    mov [ v_curs ], edi
    mov ecx, [ v_words ]
.back:
    dec edi
    mov [ ( edi * 4 ) + 0x00 ], _TOS_
    _DROP_
    loop .back
    ret

insert:
    call insert0
    mov cl, [ action ]
    xor [ edi * 4 + 0x00 ], cl
    cmp cl, 0x03                ; if we are a red token
    jnz .forward
    mov byte [ action ], 0x04    ; switch to green
    mov dword [ keypad_colour ], colour_green
    mov word [ v_hintChar ], 'g' ; mark the green keypad with a 'g'
.forward:
    ret

_word1:
    pop dword [ aword ]
    mov dword [ aword ], ex1
    ret

_word:
    mov dword [ aword ], _word1
    jmp dword quit_

tokenAction_1:
    _DUP_
    mov _TOS_, 0x01
    cmp byte [ action ], 0x04
    jz .forward2
    mov al, 0x03
.forward2:
    cmp dword [ base ], byte 0x0A
    jz .forward
    xor al, 0x10
.forward:
    _SWAP_
    mov dword [ v_words ], 0x02
    jmp short insert

tokenAction:
    test byte [ action ], 0x0A
    jnz .forward
    mov edx, _TOS_
    and edx, 0xFC000000
    jz .forward2

```

```

    cmp edx, 0xFC000000
    jnz tokenAction_1
.forward2:
    shl _TOS_, 0x05
    xor al, 0x02
    cmp byte [ action ], 0x04
    jz .forwardBack
    xor al, 0x0B
.forwardBack:
    cmp dword [ base ], byte 0x0A
    jz .forward4
    xor al, 0x10
.forward4:
    mov dword [ v_words ], 0x01
    jmp insert
.forward:
    cmp byte [ action ], 0x09
    jnz .forward3
    mov edx, _TOS_
    shl edx, 0x05
    sar edx, 0x05
    cmp edx, _TOS_
    jz .forward5
.forward3:
    _DROP_
    ret
.forward5:
    shl _TOS_, 0x05
    xor al, 0x06
    jmp short .forwardBack

enstack: ; ( ... n -- ) ; ctrlY action, delete the token at the cursor and put it into the trash buffer
    _DUP_
    mov _TOS_, [ v_cad ]
    sub _TOS_, [ v_pcad ]
    jz .forward
    mov ecx, _TOS_
    xchg _TOS_, edx
    push esi
    mov esi, [ v_cad ]
    lea esi, [ (esi * 4) - 0x04 ]
    mov edi, [ v_trash ] ; setup EDI to point to the current trash buffer address
.back:
    std
    lodsd ; _DROP_ ; loads EAX with the value pointed to by EDI = [ v_trash ]
    cld
    stosd ; stores EAX into the location pointed to by EDI = [ v_trash ] and increments
EDI
    loop .back
    xchg _TOS_, edx ;
    stosd ; stores EAX into the location pointed to by EDI and increments EDI
    mov [ v_trash ], edi ; update the current trash buffer address
    pop esi
.forward:
    _DROP_
    ret

deleteAction:
    call enstack
    mov edi, [ v_pcad ]
    mov ecx, [ v_lcad ]
    sub ecx, edi
    shl edi, 0x02
    push esi
    mov esi, [ v_cad ]
    shl esi, 0x02
    rep movsd ; copy ecx 32 bit words from ds:esi to es:edi
    pop esi
    jmp dword cursorLeft

```

```

act0:
    call enstack
    jmp dword cursorLeft

yellowAction:
    mov al, 0x01
    jmp short actt

redAction: ; red : start creating a new definition
    mov al, 0x03
    jmp short actt

greenAction: ; green, start compiling an existing definition
    mov al, 0x04
    jmp short actt

textAction:
    mov al, 0x09
    jmp short actt

CapitalAction:
    mov al, 0x0A
    jmp short actt

capitalsS_Action:
    mov al, 0x0B
    jmp short actt

grayAction:
    mov al, 0x0D
    jmp short actt

blueAction:
    mov al, 0x0E
    jmp short actt

cyanAction:
    mov al, 0x07

actt: ; ( action -- )
    mov [ action ], al
    mov dword [ aword ], insert
    mov _TOS_, [ ( _TOS_ * 4 ) + actionColourTable ]
actn:
    mov [ keypad_colour ], _TOS_
    pop _TOS_
    _DROP_
    jmp dword quit_

magentaAction: ; magenta variable action
    mov byte [ action ], 0x0C
    mov _TOS_, colour_magenta
    mov dword [ aword ], .forward
    jmp short actn
.forward:
    _DUP_
    xor _TOS_, _TOS_
    inc dword [ v_words ]
    jmp dword insert

editorExit: ; ( -- ) \ leave the editor
    pop _TOS_
    _DROP_
    mov dword [ aword ], ex1
    mov dword [ anumber ], nul
    mov byte [ alpha0 + ( 4 * 4 ) ], 0x00
    mov dword [ alpha0 + 4 ], nul0
    mov dword [ keypad_colour ], colour_yellow
    mov byte [ v_quitMode ], 0x00
    mov byte [ v_hintChar ], 0x00 ; no hint character

```

```

    jmp dword quit_

destack:
    mov edx, [ v_trash ]
    cmp edx, TRASH_BUFFER ; do not insert if we have emptied the trash buffer
    jnz .forward
    ret
.forward:
    sub edx, byte 0x08
    mov ecx, [edx+0x04]
    mov [ v_words ], ecx
.back:

    _DUP_
    mov _TOS_, [edx]
    sub edx, byte 0x04
    loop .back
    add edx, byte 0x04
    mov [ v_trash ], edx
    jmp dword insert0

editorActionTable:
    dd nul      , deleteAction    , editorExit    , destack      ;
    dd yellowAction , redAction      , greenAction  , shadow       ; y r g *
    dd cursorLeft  , cursorUp       , cursorDown   , cursorRight  ; l u d r
    dd previousBlock , magentaAction , cyanAction   , nextBlock    ; - m c +
    dd nul         , capitalS_Action , CapitalAction , textAction   ; _ S C t
    dd nul         , nul            , nul          , otherBlock   ; _ _ _ j
ekbd0:
    dd grayAction   , blueAction     , nul          , act0         ; a b _ _
    db 'x'          , '.'            , 'i'          , 0x00         ; four characters to display on the
bottom line of the keyboard

editorKeyTableHintChars: ; display the current edit colour and mode in the bottom right hand corner of
the keyboard
    db ' '          ;
    db 'yrg '       ; y r g _
    db ' '          ; l u d r
    db ' mc+'       ; - m c +
    db ' S Ct'      ; _ S C t
    db ' '          ; _ _ _ j
    db 'ab '        ; a b _ _

; Editor keypad display
; _ S C t y r g *
; c d f j l u d r
; a b _ k - m c +
; x . i

editorKeypad: ; the main editor keyboard icons
    db 'yrg*' ;
    db 0x10, 0x11, 0x12, 0x13 ; 'ludr' arrow glyphs
    db '-mc+' ;
    db ' S Ct' ;
    db 0x14, 'f', 0x17, 'j' ; "find" arrow glyphs + j
    db 'ab ' ;

set_e_main:
    mov dword [ shiftAction ], ekbd0
    mov dword [ currentKeypadIcons ], ( editorKeypad - 4 )
    mov dword [ keypad_colour ], colour_yellow
    ret

edit0:
    _DROP_
    jmp short edit2

edit_: ; ( n -- ) \ edit block n
    mov ecx, [ v_blk ]
    mov [ v_otherBlock ], ecx ; save the current edit block to the "other" block variable

```

```

    mov [ v_blk ], _TOS_          ; set the new edit block
    _DROP_                        ; discard n, and drop through to "e_"
e_:
    mov byte [ v_quitMode ], 0xFF
    call refresh
plus_e:
    mov dword [ anumber ], tokenAction
    mov byte [ alpha0+4*4 ], 0x25
    mov dword [ alpha0 + 4 ], edit0
edit2:
    call set_e_main
    .back:
    call clearHintChar
    call get_key_
    push _TOS_
    mov al, [ editorKeyTableHintChars + _TOS_ ]
    mov [ v_hintChar ], _TOS_
    pop _TOS_
    call [ ( _TOS_ * 4 ) + editorActionTable ]
    _DROP_
    jmp short .back

convertAddress:      ; ( a32 -- )    set up the block at the given 32 bit cell address, including the
cursor position
    mov _SCRATCH_, _TOS_
    and _SCRATCH_, 0x00FF
    mov [ v_curs ], _SCRATCH_    ; cell offset in block
    call cellAddressToBlock
    mov [ v_blk ], _TOS_
    _DROP_
    ret

editAddress:      ; ( a32 -- )    edit the block at the given 32 bit cell address, including the cursor
position
    call convertAddress
    call abort_e2          ; abort and show the editor display
    ret

keypd_:      ; display the keypad vectors and display characters at the address on top of the return stack
    pop edx          ; keypd_ is followed by call table then keymap
    mov [ vector ], edx          ; edx points to the next colorForth word to be executed
    add edx, ( 28 * 5 )          ; 28 keys, 5 bytes per compiled call
    mov [ currentKeypadIcons ], edx
    sub edx, byte +16
    mov [ shiftAction ], edx
.back:
    call get_key_          ; calls pause_ while waiting for a character
    mov edx, [ vector ]
    add edx, _TOS_
    lea edx, [ ( _TOS_ * 4 ) + edx + 0x05 ]
    add edx, [ edx - 0x04 ]
    _DROP_
keypd1:
    call edx
    jmp short keypd_.back

; *****
; QWERTY support
; *****

qwertyKeyboard:
    dd 0
    dd 0
    dd 0
    dd 0x01040f17          ; 'qwer'
    dd 0
    dd 0

qwertyToggleBase:
    xor dword [ setCurrentBase ], ((setBase_decimal - $$) ^ (setBase_hex - $$))

```

```

        xor byte [ ( numb0 + 12 ) ], 0x2F
qwertyToggleBase1:
;   call [ setCurrentBase ]
;   mov dword [ qwertyKeyboard ], 0x00          ; '' => decimal
;   cmp dword [ base ], byte +0x10
;   jnz .forward
;   mov dword [ qwertyKeyboard ], 0x00150414    ; 'hex'
; .forward:
;   mov dword [ currentKeypadIcons ], keypd1
;   mov dword [ shiftAction ], qwertyKeyboard
    ret

qwertyAction4:
    call qwertyToggleBase
    jmp qwertyAction3

qwertyActionTable:
    dd endn, endn, xn, qwertyAction3, qwertyAction4

qwertyFunction1:
    call right
    db 0xC7
    add _TOS_, ( qwertyKeyboard + 4 )
    push es
    push ss
    or [ _TOS_ ], _TOS_
    call qwertyToggleBase1
    mov byte [ v_sign ], 0x00
    mov _TOS_, [ v_digin ]
qwertyAction5:
    call get_qwerty_key_
    jz .forward4
    jmp dword [ _TOS_ * 4 + qwertyActionTable - 0x200 ]
.forward4:
    test _TOS_, _TOS_
    jng qwertyAction3
    cmp al, 0x23
    jz .forward3
    mov _TOS_, [ v_digin ]
    cmp _TOS_, [ base ]
    jns .forward2
    test byte [ v_sign ], 0xFF
    jz .forward
    neg _TOS_
.forward:
    mov edx, [ esi ]
    imul edx, [ base ]
    add edx, _TOS_
    mov [ esi ], edx
.forward2:
    jmp short qwertyAction3
.forward3:
    xor [ v_sign ], _TOS_
    neg dword [ esi ]

qwertyAction3:
    _DROP_
    jmp short qwertyAction5

qwertyToggleBaseTable2:
    dd lj, lj, x

qwertyFunction2:
    mov dword [ ( qwertyKeyboard + 4 ) ], 0x02150402 ; 'text'
    call right
    mov dword [ v_words ], 0x01
    mov dword [ chars ], 0x01
    _DUP_
    mov dword [ esi ], 0x00
    mov byte [ bits_ ], 0x1C

```



```

.back:
    jz .forward
    cmp _TOS_, 0x83
    jns .forward
    jmp dword [ _TOS_*4 + qwertToggleBaseTable2 - 0x200 ]
.forward:
    test _TOS_, _TOS_
    jng .forward2
    cmp _TOS_, 0x30
    jns .forward2
    _DUP_
    call echo_
    call pack_
    inc dword [ chars]
.forward2:
    _DROP_
    call get_qwerty_key_
    jmp short .back

qwertyAction2:
    call qwertToggleBase
    jmp dword nul0

qwertyAction1:
    jmp dword [ alpha0 + 4 ]

qwertyTable1:
    dd nul0
    dd nul0
    dd nul0
    dd qwertyAction1
    dd qwertyAction2

qwertyDoAction:
    mov dword [ ( qwertyKeyboard + 4 ) ], 0x00    ; clear the 'text' string
    mov dword [ shiftAction ], qwertyKeyboard
    mov dword [ currentKeypadIcons ], keypd1

.back2:
    call get_qwerty_key_
    jz .forward
    jmp dword [ ( _TOS_ * 4 ) + qwertyTable1 - 0x0200 ]

.forward:
    cmp al, 0x30
    jnz .back
    mov dword [ ( qwertyKeyboard + 4 ) ], 0x02150402 ; 'text'
    _DROP_
    jmp short .back2

.back:
    test _TOS_, _TOS_
    jng .forward3
    test dword [ ( qwertyKeyboard + 4 ) ], 0xFFFFFFFF
    jnz .forward2
    cmp byte [ v_digin ], 0x0A
    js qwertFunction1
.forward2:
    cmp _TOS_, 0x30
    jns .forward3
    call qwertyFunction2
    call [ aword ]
    _DUP_
.forward3:
    _DROP_
    jmp dword quit_

qwerty:
    ; selects QWERTY keyboard entry
    mov dword [ x_qwerty ], qwertyDoAction
    ret

```

```

; *****

abort_action:
    cmp edi, ( RELOCATED / 4 ) ; if we are compiling a block, show the location of the error
    ; edi is a cell address, so divide by 4
    jc .forward
    _DUP_
    mov _TOS_, [ v_blk ]
    mov [ v_otherBlock ], _TOS_ ; save the last block to be edited
    mov _TOS_, edi
    call convertAddress
.forward:
    mov esp, RETURN_STACK_0
    cmp esi, ( DATA_STACK_0 + 4 )
    jc .forward2
    mov esi, ( DATA_STACK_0 + 4 )
.forward2:
    mov dword [ tokenActions + ( 3 * 4 ) ], forthd
    mov dword [ tokenActions + ( 4 * 4 ) ], qcompile
    mov dword [ tokenActions + ( 5 * 4 ) ], cnum
    mov dword [ tokenActions + ( 6 * 4 ) ], cshort
    mov _TOS_, 0x3F ; '?' character to follow the display of the unknown word
    call echo_
;    jmp abort_e2
    jmp dword quit_

; *****

rquery: ; r?
    _DUP_
    mov _TOS_, RETURN_STACK_0
    sub _TOS_, esp
    shr _TOS_, 1
    shr _TOS_, 1
    ret

boot:
    ; see http://wiki.osdev.org/PS2\_Keyboard#CPU\_Reset
    mov al, 0xFE
    out 0x64, al
    jmp short $ ; we should never get here, because the processor will be rebooted... stop here
just in case

wipe: ; ( -- ) \ wipe the currently edited block
    _DUP_
    mov _TOS_, [ v_blk ]
    mov ecx, 0x40
wipe2:
    push edi
    call blockToCellAddress ; add the RELOCATED block number offset and convert to cell address
    shl _TOS_, 2 ; convert to byte address
    mov edi, _TOS_
    xor _TOS_, _TOS_
    rep stosd ; stores eax into the location pointed to by edi then increments edi by 4, does this
ecx times
    pop edi
    _DROP_
    ret

wipes: ; ( startblock# #blocks -- ) \ wipes #blocks starting from block startblock# ( was erase )
    mov ecx, _TOS_
    shl ecx, 0x06 ; convert blocks to cells, multiply by 64
    _DROP_
    jmp wipe2

copy_: ; ( blk -- ) \ copy the given block (and shadow) to the currently displayed block (and shadow)
    cmp _TOS_, byte 0xC ; below block 12 is machine code
    jc abort
    push edi
    push esi

```

```

    push ecx
    call blockToCellAddress      ; source block
    shl _TOS_, 0x02             ; convert cell address to byte address
    mov esi, _TOS_
    mov _TOS_, [ v_blk ]
    call blockToCellAddress      ; destination block
    shl _TOS_, 0x02             ; convert cell address to byte address
    mov edi, _TOS_
    mov ecx, 0x0200
    rep movsd                   ; copy ecx 32 bit words from ds:esi to es:edi
    pop ecx
    pop esi
    pop edi
    _DROP_
    ret

debug:
    mov dword [ v_xy ], 0x302B5
    _DUP_
    mov _TOS_, [ main ]
    push dword [_TOS_]
    call dotHex
    _DUP_
    pop _TOS_
    call dotHex
    _DUP_
    mov _TOS_, [ draw ]
    call dotHex
    _DUP_
    mov _TOS_, esi
    jmp dword dotHex

; *****

tic0:
    dec dword [ v_words ]
    jz .forward
    _DROP_
    jmp short tic0
.forward:
    ret

tic_   ; ( -- a ) \ return the byte address of the next word entered
    call _word      ; allow user to enter the word to search for
    call tic0       ; remove the entered word from the stack
    call find_      ; find the word in the dictionary, return its index in ecx
    jnz abort
    mov _TOS_, [ ( ecx * 4 ) + ForthJumpTable ] ; return the word's address from the jump table
    ret

itick:
    and _TOS_, 0xFFFFFFFF
    call find_
    mov _TOS_, [ ( ecx * 4 ) + ForthJumpTable ]
    ret

; *****

; ToDo: fix this!!!
showWords_:      ; ( -- ) \ show all words in the Forth wordlist
    call show
    push edi
    call setRed
    lea edi, [ ForthNames - 4 ] ; set edi to the bottom of the Forth name table
    mov ecx, [ v_ForthWordCount ] ; count of Forth wordlist words
.loop:
    call showSF_EDI_      ; show one Shannon-Fano encoded word
    call space_
    inc edi
    loop .loop

```

```

    pop edi
    ret

words_:
    call showWords_
    ret

; *****

; Int 0x13 AH Return Code error type
; 0x00 Success
; 0x01 Invalid Command
; 0x02 Cannot Find Address Mark
; 0x03 Attempted Write On Write Protected Disk
; 0x04 Sector Not Found
; 0x05 Reset Failed
; 0x06 Disk change line 'active'
; 0x07 Drive parameter activity failed
; 0x08 DMA overrun
; 0x09 Attempt to DMA over 64kb boundary
; 0x0A Bad sector detected
; 0x0B Bad cylinder (track) detected
; 0x0C Media type not found
; 0x0D Invalid number of sectors
; 0x0E Control data address mark detected
; 0x0F DMA out of range
; 0x10 CRC/ECC data error
; 0x11 ECC corrected data error
; 0x20 Controller failure
; 0x40 Seek failure
; 0x80 Drive timed out, assumed not ready
; 0xAA Drive not ready
; 0xBB Undefined error
; 0xCC Write fault
; 0xE0 Status error
; 0xFF Sense operation failed

; *****
; 16 bit BIOS disk read/write from 32 bit
; *****

; set the required parameters into the DAP buffer for the LBA BIOS extended read/write calls.
; Also set up the extra DAP buffer values for use by the CHS BIOS calls, if the LBA call fails.
; This is to avoid returning from 16 bit mode to calculate the values.
setupDAP_:  ( sector n cmd -- ) \ setup the DAP for the given LBA sector number

    push edi

    xor ecx, ecx
    mov edi, (data_area - $$ + BOOTOFFSET) ; setup the data index pointer
    mov cx, [ word di + ( driveinfo_Drive_DX - data_area ) ] ; restore the boot drive into dl
    mov edi, DAP_BUFFER
    mov word [ edi + o_Int13_DAP_saved_DX ], cx ; setup DX value returned by the BIOS

    mov word [ edi + o_Int13_DAP_readwrite ], ax ; set the read/write cmd value, 0x0000 or 0x0001
    _DROP_

    ; limit the number of sectors to the size of the SECTOR_BUFFER
    cmp _TOS_, ( SECTOR_BUFFER_SIZE / 0x0200 )
    js .forward
    mov _TOS_, ( SECTOR_BUFFER_SIZE / 0x0200 )
.forward:
    mov word [ edi + o_Int13_DAP_num_sectors ], ax
    _DROP_

    mov dword [ edi + o_Int13_DAP_LBA_64_lo ], eax
    push eax ; save for later

    xor eax, eax
    mov dword [ edi + o_Int13_DAP_LBA_64_hi ], eax

```

```

; buffer within low 16 bits of address space
mov word [ edi + o_Int13_DAP_segment ], ax
mov ax, ( SECTOR_BUFFER )
mov word [ edi + o_Int13_DAP_address ], ax

; set the configuration buffer values from the registers
mov eax, 0x0010
mov word [ edi + o_Int13_DAP_size ], ax ; setup DAP buffer size

; setup values for CHS BIOS disk calls

pop eax ; restore the start sector number
add eax, [ bootsector - $$ + BOOTOFFSET ] ; add the bootsector from the drive parameter table

push eax ; save it while we calculate heads*sectors-per-track
mov al, [ driveinfo_Head - $$ + BOOTOFFSET ] ; index of highest-numbered head
inc al ; 1-base the number to make count of heads
mul byte [ driveinfo_SectorsPertrack - $$ + BOOTOFFSET ] ; sectors per track
mov ebx, eax
pop eax
xor edx, edx ; clear high 32 bits
div ebx ; leaves cylinder number in eax, remainder in edx
mov ecx, eax ; store cylinder number in another register
mov eax, edx ; get remainder into AX
mov bl, [ driveinfo_SectorsPertrack - $$ + BOOTOFFSET ] ; number of sectors per track
div bl ; head number into AX, remainder into DX
mov bl, al ; result must be one byte, so store it in BL
rol ecx, 8 ; high 2 bits of cylinder number into high 2 bits of CL
shl cl, 6 ; makes room for sector number
or cl, ah ; merge cylinder number with sector number
inc cl ; one-base sector number
mov word [ edi + o_Int13_DAP_saved_CHS_CX ], cx ; also save the calculated CX value
mov cx, [ driveinfo_Drive_DX - $$ + BOOTOFFSET ] ; drive number in low 8 bits
mov ch, bl ; place head number in high bits
mov word [ edi + o_Int13_DAP_saved_CHS_DX ], cx ; also save the calculated DX value

pop edi
_DROP_

ret

; *****
; BIOS read/write 512 byte LBA sectors
; *****

BIOS_ReadWrite_Sector_LBA: ; ( -- ) \ try to read or write using the extended disk BIOS calls,
; \ if that fails, try the CHS BIOS call. Parameters are in the DAP buffer.

pushf ; save the processor flags, especially interrupt enable

%ifdef NOT_BOCHS
call restore_BIOS_idt_and_pic ;
%endif

_DROP_
xor _TOS_, _TOS_
call lidt_ ; Load the BIOS Interrupt Descriptor Table

call setRealModeAPI
[BITS 16] ; Real Mode code (16 bit)
mov si, DAP_BUFFER
mov byte ah, [ si + o_Int13_DAP_readwrite ] ; 0x00 for read, 0x01 for write
or ah, 0x42 ; BIOS extended read/write
mov al, 0x00
mov dx, [ si + o_Int13_DAP_saved_DX ]
int 0x13
cli ; BIOS might have left interrupts enabled

mov word [ si + o_Int13_DAP_returned_AX ], ax ; save the value in AX that the BIOS call returned

```

```

jnc .forward
mov si, DAP_BUFFER

mov byte ah, [ si + o_Int13_DAP_readwrite ] ; 0x00 for read, 0x01 for write
or ah, 0x02 ; CHS BIOS mode, read all sectors, set above
mov al, byte [ si + o_Int13_DAP_num_sectors ] ; restore the number of sectors saved by setupDAP_

mov word cx, [ si + o_Int13_DAP_saved_CHS_CX ] ; restore the CX value calculated by sector_chs
mov word dx, [ si + o_Int13_DAP_saved_CHS_DX ] ; restore the DX value calculated by sector_chs
mov word bx, [ si + o_Int13_DAP_address ] ; restore the address saved by setupDAP_
int 0x13
cli ; BIOS might have left interrupts enabled

mov si, DAP_BUFFER
mov word [ si + o_Int13_DAP_returned_AX ], ax ; the BIOS call returned AX
mov ax, 0x0001
jc .forward2
mov ax, 0x0000
.forward:
mov [ si + o_Int13_DAP_returned_carry_flag ], ax ; the BIOS call returned carry flag
.forward2:
mov [ si + o_Int13_DAP_returned_carry_flag ], ax ; the BIOS call returned carry flag

call setProtectedModeAPI ; called from 16 bit code, returns to 32 bit code
[BITS 32] ; Protected Mode code (32 bit)

#ifdef NOT_BOCHS
call restore_new_idt_and_pic
#endif

.DUP_
mov _TOS_, INTERRUPT_VECTORS
call lidt_ ; Load the new Interrupt Descriptor Table

popf ; restore the processor flags, especially interrupt enable

ret

Read_Sector_LBA: ; ( sector n -- ) "rlba" GetFlag returns 0 for success
.DUP_
mov eax, 0x0000 ; read command
call setupDAP_ ; setup up the DAP table using 3 items from the stack ( start n cmd --
)
cli ; disable interrupts
pushad ; Pushes all general purpose registers onto the stack
call BIOS_ReadWrite_Sector_LBA
popad ; restore the registers pushed by pushad
ret

Write_Sector_LBA: ; ( sector n -- ) "wlba"
.DUP_
mov eax, 0x0001 ; write command
call setupDAP_ ; setup up the DAP table using 3 items from the stack ( start n cmd --
)
cli ; disable interrupts
pushad ; Pushes all general purpose registers onto the stack
call BIOS_ReadWrite_Sector_LBA
popad ; restore the registers pushed by pushad
ret

ReadSectors: ; ( a sector n -- a' ) \ read n sectors from sector into address a
call Read_Sector_LBA ; reads n sectors starting from sector into the SECTOR_BUFFER

push esi ; esi is changed by rep movsw

mov esi, DAP_BUFFER
xor ecx, ecx
mov word cx, [ si + o_Int13_DAP_num_sectors ] ; restore the number of sectors saved by setupDAP_
mov ebx, ecx ; save number of sectors for later
mov esi, SECTOR_BUFFER ; source address

```

```

    mov edi, eax                ; destination address
    shl ecx, 0x07              ; 512 bytes in cells = 2 ** 7
    rep movsd                  ; does not change AX , it moves DS:SI to ES:DI and increments SI and
DI
    ; ( a -- a' )
    mov ecx, ebx
    shl ecx, 0x09              ; 512 bytes in bytes = 2 ** 9
    add eax, ecx               ; increment the address that is TOS

    pop esi
    ; ( a -- a' sector' )
    _DUP_
    push esi
    mov esi, DAP_BUFFER        ; esi is changed by rep movsd above
    xor ecx, ecx
    mov word cx, [ si + o_Int13_DAP_LBA_64_lo ] ; restore the start sector
    pop esi
    mov eax, ecx
    add eax, ebx

;    call GetFlag
    ret

WriteSectors:    ; ( a sector n -- a' ) \ write n sectors starting at sector from address a

    push ecx
    push edx

    mov edx, [ esi + 4 ]      ; save a from stack in edx

    push esi                  ; esi is also changed by rep movsw
    mov esi, DAP_BUFFER
    xor ecx, ecx
    mov word cx, [ si + o_Int13_DAP_num_sectors ] ; restore the number of sectors saved by setupDAP_
    mov ebx, ecx              ; save number of sectors for later

    shl ecx, 0x07            ; 512 bytes in cells = 2 ** 7

    mov esi, edx              ; source address
    mov edi, SECTOR_BUFFER    ; destination address
    rep movsd                 ; does not change AX , it moves DS:SI to ES:DI and increments SI and
DI
    pop esi

    push ebx
    call Write_Sector_LBA     ; writes n sectors starting from sector from the SECTOR_BUFFER
    pop ebx
;    push esi                  ; esi is also changed by rep movsw

    ; ( a -- a' )
    mov ecx, ebx
    shl ecx, 0x09            ; 512 bytes in bytes = 2 ** 9
    add eax, ecx              ; increment the address that is TOS

;    pop esi
    ; ( a -- a' sector' )
    _DUP_
    push esi
    mov esi, DAP_BUFFER        ; esi is changed by rep movsd above
    xor ecx, ecx
    mov word cx, [ si + o_Int13_DAP_LBA_64_lo ] ; restore the start sector
    pop esi
    mov eax, ecx
    add eax, ebx

    pop edx
    pop ecx

```

```

ret

SaveAll_: ; ( -- ) "sss"
pushf ; save the processor flags, especially interrupt enable
cli

_DUP_
xor eax, eax
call block_
_DUP_
xor eax, eax
mov ecx, 0x21 ; 32 x 16 Kbytes= 512 + 32 Kbytes
.back:
_DUP_
mov eax, 0x20 ; 32 x 512 byte sectors = 16 Kbytes
call WriteSectors ; ( a sector n -- a' ) \ write n sectors starting at sector from address a
loop .back
_DROP_
_DROP_

; ; repeat the first group of sectors, to flush the save
; _DUP_
; xor eax, eax
; call block_
; _DUP_
; xor eax, eax
; mov ecx, 0x01 ; 1 x 16 Kbytes= 162 Kbytes
; .back2:
; _DUP_
; mov eax, 0x20 ; 32 x 512 byte sectors = 16 Kbytes
; call WriteSectors ; ( a sector n -- a' ) \ write n sectors starting at sector from address a
; loop .back2
; _DROP_
; _DROP_

; ; repeat the last sector, to flush the save
; _DUP_
; ; address
; mov eax, LAST_BLOCK_NUMBER
; call block_
; _DUP_
; ; sector number
; mov eax, ( LAST_BLOCK_NUMBER * 2 ) ; 01 x 512 byte sectors = 512 bytes, just write one sector
; _DUP_
; ; number of 512 byte sectors to write
; mov eax, 0x01 ; 01 x 512 byte sectors = 512 bytes, just write one sector
; call WriteSectors ; ( a sector n -- a' ) \ write n sectors starting at sector from address a
; _DROP_
; _DROP_

popf ; restore the processor flags, especially interrupt enable
ret

GetFlag: ; ( -- error | 0 ) 0 for success, else the error type ( eax == 0x100 is Invalid Command )
_DUP_
xor eax, eax
push edi
mov edi, DAP_BUFFER
mov ax, [ edi + o_Int13_DAP_returned_carry_flag ] ; the BIOS call returned carry flag
add ax, 0
jz .forward
mov ax, [ edi + o_Int13_DAP_returned_AX ] ; the BIOS call returned error value in ax
.forward:
pop edi
ret

%if 0
BIOS_Read_Sector_CHS:
call setRealModeAPI
[BITS 16] ; Real Mode code (16 bit)

```



```

    mov si, DAP_BUFFER
    mov al, byte [ si + o_Int13_DAP_num_sectors ] ; setup the number of sectors saved by setupDAP_
;    and al, 0x0F ; limit to 16 sectors
    mov ah, 0x02 ; CHT BIOS mode, read al sectors, set above
    mov word cx, [ si + o_Int13_DAP_saved_CHS_CX ] ; setup the CX value calculated by sector_chs
    mov word dx, [ si + o_Int13_DAP_saved_CHS_DX ] ; setup the DX value calculated by sector_chs
    mov word bx, [ si + o_Int13_DAP_address ] ; setup the address saved by setupDAP_
    int 0x13
    cli ; BIOS might have left interrupts enabled

    mov si, DAP_BUFFER
    mov word [ si + o_Int13_DAP_returned_AX ], ax ; the BIOS call returned AX
    mov ax, 0x0001
    jc .forward
    mov ax, 0x0000
    .forward:
    mov [ si + o_Int13_DAP_returned_carry_flag ], ax ; the BIOS call returned carry flag

    call setProtectedModeAPI ; called from 16 bit code, returns to 32 bit code
[BITS 32] ; Protected Mode code (32 bit)
    ret

; rchs:
Read_Sector_CHS: ; ( sector n -- f ) "rchs" returns 0 for success
    call setupDAP_ ; ( start n -- ) store the sector number into the Disk Address Packet
    cli ; disable interrupts
    pushad ; Pushes all general purpose registers onto the stack
    call BIOS_Read_Sector_CHS
    popad ; restore the registers pushed by pushad
;    _DROP_
    jmp GetFlag

; wcht:
Write_Sector_CHS: ; ( sector -- ) "wcht"
    call setupDAP_ ; store the sector number into the Disk Address Packet
    cli ; disable interrupts
    pushad ; Pushes all general purpose registers onto the stack
    call BIOS_Read_Sector_CHS
    popad ; restore the registers pushed by pushad
    ret

%endif

; *****
; *****

%if 0
[BITS 16] ; Real Mode code (16 bit)
storeBefore: ; ( -- ) \ store registers to the V_REGS array
    mov word [ V_REGS + 0x00 ], ax
    mov word [ V_REGS + 0x04 ], bx
    mov word [ V_REGS + 0x08 ], cx
    mov word [ V_REGS + 0x0C ], dx
    mov word [ V_REGS + 0x10 ], si
    mov word [ V_REGS + 0x14 ], di
    mov word [ V_REGS + 0x18 ], bp
    push ax ; save eax
    pushfd ; push the 32 bit eflags register onto the stack
    pop ax ; and pop it off into eax
    mov word [ V_REGS + 0x1C ], ax ; eflags
    pop ax
    mov word [ V_REGS + 0x1E ], ax ; eflags top 16 bits
    pop ax ; restore eax
    ret

storeAfter: ; ( -- ) \ store registers to the V_REGS array
    mov word [ V_REGS + 0x20 ], ax
    mov word [ V_REGS + 0x24 ], bx
    mov word [ V_REGS + 0x28 ], cx
    mov word [ V_REGS + 0x2C ], dx

```

```

    mov word [ V_REGS + 0x30 ], si
    mov word [ V_REGS + 0x34 ], di
    mov word [ V_REGS + 0x38 ], bp
    push ax                ; save eax
    pushfd                 ; push the 32 bit eflags register onto the stack
    pop ax                 ; and pop it off into eax
    mov word [ V_REGS + 0x3C ], ax ; eflags
    pop ax
    mov word [ V_REGS + 0x3E ], ax ; eflags top 16 bits
    pop ax                 ; restore eax
    ret
[BITS 32]                  ; Protected Mode code (32 bit)

BIOS_thunk:                ; ( -- ) \ call the BIOS - registers will have previously been setup
    call setRealModeAPI
[BITS 16]                  ; Real Mode code (16 bit)
    push ax
    push es                ; this operation messes with ES
    push di                ; and DI
    call storeBefore
    int 0x13
    jc $                   ; stop here on error
    call storeAfter
    pop di
    pop es
    pop ax
    cli                    ; BIOS might have left interrupts enabled
    call setProtectedModeAPI ; called from 16 bit code, returns to 32 bit code
[BITS 32]                  ; Protected Mode code (32 bit)
    ret

%endif

%if 0
th_:                        ; ( ax bx cx dx si di es -- w ) \ th ( thunk to BIOS Int 0x13 )
    ; eax = 0x DH DL AH AL , returns in same order
    cli                    ; disable interrupts
    pushad                 ; Pushes all general purpose registers onto the stack in the following order:
    ; EAX, ECX, EDX, EBX, ESP, EBP, ESI, EDI. The value of ESP is the value before the actual push
of ESP
    ; 7 6 5 4 3 2 1 0 offset in cells from ESP

;    call setupDAP_

    push edi
    mov di, (data_area - $$ + BOOTOFFSET) ; setup the data index pointer
    mov dx, [ byte di + ( driveinfo_Drive_DX - data_area) ] ; restore the boot drive from dx (and head? )
;    mov dl, 0x80
    mov ebx, SECTOR_BUFFER
    mov eax, ( 0x0200 + ( ( SECTOR_BUFFER_SIZE / 512 ) & 0xFF ) ) ; read n sectors to fill the buffer
    mov ecx, 0x0201 ; cylinder | sector

    call BIOS_thunk

    pop edi
    popad ; restore the stack values pushed by pushad
    ret
%endif
%if 0
XXXrsect_:                ; ( sector -- ax ) \
    pushad ; Pushes all general purpose registers onto the stack
    push edi

;    call sector_chs ; store th sector number into the Disk Address Packet

    mov di, (data_area - $$ + BOOTOFFSET) ; setup the data index pointer
    mov dx, [ byte di + ( driveinfo_Drive_DX - data_area) ] ; restore the boot drive from dx (and head? )
;    mov dl, 0x80

    cli                    ; disable interrupts

```

```

;   mov esi, DAP_BUFFER
;   _DUP_
mov eax, 0x0201 ; BIOS read, one sector
mov bx, SECTOR_BUFFER
call BIOS_thunk

pop edi
popad ; restore the stack values pushed by pushad
ret
%endif

; *****
; *****

#define FORTH_INITIAL_WORD_COUNT ( ( ForthJumpTableROM_end - ForthJumpTableROM ) / 4 ) ; in cells
#define MACRO_INITIAL_WORD_COUNT ( ( MacroJumpTableROM_end - MacroJumpTableROM ) / 4 ) ; in cells

warm: ; warm start
mov _SCRATCH_, STACK_MEMORY_START ; start of stack memory area
mov ecx, ( TOTAL_STACK_SIZE >> 2 ) ; number of 32 bit cells to fill with the pattern
.back:
mov dword [ _SCRATCH_ ], 0x55555555 ; fill with this pattern
add _SCRATCH_, 0x04
loop .back

xor ecx, ecx ; assumed by initshow to have been previously zeroed
; call initshow ; sets up do-nothing "show" task
call refresh ; starts the editor display task
call init serv1 ; sets up do-nothing "serv1" task
call init serv2 ; sets up do-nothing "serv2" task ToDo: fix the serv2 task...
; call stop ; turn off floppy motor and point trash to floppy buffer
; mov byte [ dma_ready ], 0x01 ; not ready
mov dword [ v_ForthWordCount ], FORTH_INITIAL_WORD_COUNT ; initial #words
mov dword [ v_MacroWordCount ], MACRO_INITIAL_WORD_COUNT ; initial #macros
mov dword [ v_trash ], TRASH_BUFFER

push esi

;Forth wordlist
lea esi, [ ForthNamesROM ]
mov edi, ForthNames
mov ecx, [ v_ForthWordCount ]
rep movsd ; copy ecx 32 bit words from ds:esi to es:edi
lea esi, [ ForthJumpTableROM ]
mov edi, ForthJumpTable
mov ecx, [ v_ForthWordCount ]
rep movsd ; copy ecx 32 bit words from ds:esi to es:edi
; Macro wordlist
lea esi, [ MacroNamesROM ]
mov edi, MacroNames
mov ecx, [ v_MacroWordCount ]
rep movsd ; copy ecx 32 bit words from ds:esi to es:edi
lea esi, [ MacroJumpTableROM ]
mov edi, MacroJumpTable
mov ecx, [ v_MacroWordCount ]
rep movsd ; copy ecx 32 bit words from ds:esi to es:edi

pop esi

mov dword [ v_H ], H0
mov dword [ x_qwerty ], 0x00 ; select non-qwerty mode
mov dword [ v_offset ], ( RELOCATED >> ( 2 + 8 ) ) ; 0x10000 >> 2 >> 8, offset of RELOCATED block 0 as
1024 byte block number

; Historical note. This bug took about 15 hours to find and fix...
; Below is code to track down a bug : Block 64 offset 0x7C contained 0x800
; The code with the two test functions was re-compiled using the cf2022Ref.img file
; Then block 64 was manually fixed ": rtc 94 ld ;"
; The source blocks were saved with "sa"
; cf2022 was restarted without recompilation

```

```

; Looking at blocks 506 and 507 showed that the bug occurred between the two copy f.unctions
;
;   ; OK at this point
;   mov _SCRATCH_, [ v_blk ]
;   mov dword [ v_blk ], 506   ; block 506 shows corruption
;   mov _TOS_, 64
;   call copy_
;   mov [ v_blk ], _SCRATCH_

; setup v_bytesPerLine
mov _TOS_, [ vesa_XResolution ]
and _TOS_, 0xFFFF
imul _TOS_, BYTES_PER_PIXEL
mov [ v_bytesPerLine ], _TOS_
; was :      mov [ v_bytesPerLine + RELOCATED ], _TOS_    <--- BUG!!!

;   ; NOT OK at this point
;   mov _SCRATCH_, [ v_blk ]
;   mov dword [ v_blk ], 507   ; block 506 shows corruption???
;   mov _TOS_, 64
;   call copy_
;   mov [ v_blk ], _SCRATCH_

; set up fov
mov _TOS_, [ vesa_YResolution ]
and _TOS_, 0x000FFFFF
mov _SCRATCH_, _TOS_
shl _SCRATCH_, 1
shr _TOS_, 1
add _TOS_, _SCRATCH_
imul _TOS_, 10
mov [ v_fov ], _TOS_

; select which code to use, depending on the display mode
mov byte [ displayMode ], 0
cmp word [ vesa_XResolution ], scrnw1
jz .forward
mov byte [ displayMode ], 1
.forward:

; *****
; miscellaneous setup
; *****

call randInit_   ; initialise the Marsaglia Pseudo Random Number Generator
call initIconSize ; sets up the size of an icon (glyph) according to the 800x600 or 1024x768 display
size
call cursorHome  ; setup the initial cursor location
call c_          ; clear the stack

; *****
; erase the DAP buffer, for the Int 0x13 Disk Address Packet (DAP)
; *****
_DUP_
mov _TOS_, SECTOR_BUFFER
_DUP_
mov _TOS_, SECTOR_BUFFER_SIZE
call erase_

; *****
; load the colorForth source starting at the first colorForth source block
; *****
_DUP_
mov _TOS_, START_BLOCK_NUMBER
_DUP_
call _load_      ; not sure why we need this...
jmp dword quit_

; *****
; *****

```

```

pad_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_pad
    ret

v_srch:    ; variables to search for a token name
    dd 0xC4B80000 ; token name "pad"
    dd 0          ; token name extension (optional)
    dd 0          ; current found address
    dd 0          ; last found address
    dd ( START_BLOCK_NUMBER * 1024 ) ; start searching from here
    dd ( ( LAST_BLOCK_NUMBER + 1 ) * 1024 ) ; end the search here

vsrch_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_srch
    ret

srch_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_srch
    ret

; align 4, db 0 ; variables must be on dword boundary so that "dump" can show them correctly
;
; hsvv:    ; the start address of the pre-assembled high level Forth words
;    dd 0
;    times 0x28 db 0

xy_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_xy
    ret

fov_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_fov
    ret

tokenActions_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS tokenActions
    ret

last_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS last
    ret

version_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS version
    ret

vframe_:    ; ( -- a ) \ return the video frame address, where we create the image to be displayed
    _DUP_
    mov _TOS_, [ vframe ]
    ret

vars_:
    _DUP_
    LOAD_RELATIVE_ADDRESS vars
    ret

base_:
    _DUP_
    LOAD_RELATIVE_ADDRESS base
    ret

```

```

hex_:
    mov byte [ base ], 16
    ret

decimal_:
    mov byte [ base ], 10
    ret

block_: ; ( block -- address ) \ : block ( n -- n ) $400 * ; address is in bytes
    shl _TOS_, 0x0A
    add _TOS_, RELOCATED
    ret

scrnw_: ; ( -- n ) screen width ( number of horizontal pixels )
    _DUP_
    xor _TOS_, _TOS_
    mov word ax, [ vesa_XResolution ]
    ret

scrnh_: ; ( -- n ) screen height ( number of vertical pixels )
    _DUP_
    xor _TOS_, _TOS_
    mov word ax, [ vesa_YResolution ] ; v_scrnh
    ret

bpp_: ; ( -- n ) bits per pixel
    _DUP_
    xor _TOS_, _TOS_
    mov byte al, [ vesa_BitsPerPixel ] ; v_bitsPerPixel
    ret

iconw_: ; ( -- n ) icon width ( number of pixels between characters, fixed font width )
    _DUP_
    mov _TOS_, [ v_iconw ]
    ret

iconh_: ; ( -- n ) icon height ( number of pixels between lines )
    _DUP_
    mov _TOS_, [ v_iconh ]
    ret

counter_: ; ( -- n ) roughly 1 ms counter
    _DUP_
    RDTSC ; Read Time-Stamp Counter https://c9x.me/x86/html/file\_module\_x86\_id\_278.html
    mov ecx, 1000
    idiv ecx
    ret

; : drop ( lodsd, flags unchanged, why sp is in ESI )
; : a! ?lit if $BA 1, , ; then $D08B 2, drop ;
; : p@ ( a-n ) qdup a! $EC 1, ;
; : p! ( na- ) a! $EE 1, drop ;
; ( Real Time Clock )
; : rtc@ ( t-c ) $70 p! $71 p@ ;
; : rtc! ( ct- ) $70 p! $71 p! ;
; : hi ( -- ) #10 rtc@ $80 and drop 0if hi ; then ;
; : lo ( -- ) #10 rtc@ $80 and drop if lo ; then ;
; : calkhz ( -- ) hi lo counter hi lo counter swap -
;   dup onesecc ! #1 rshift #250 + #500 / dup khz ! ;
; : ms ( n- ) khz @ * counter + begin pause dup counter
;   invert + drop -if drop ; then end drop ;

p70_fetch: ; ( reg -- c )
    mov edx, 0x70 ; db 0xBA dd 0x70
    IN AL, DX ; db 0xEC
    ret

p70_store: ; ( c reg -- )
    mov edx, 0x70 ; db 0xBA dd 0x70

```

```

    OUT DX, AL      ; db 0xEE
    _DROP_
    _DROP_
    ret

p71_fetch: ; ( reg -- c )
    mov edx, 0x71   ; db 0xBA dd 0x71
    IN AL, DX       ; db 0xEC
    ret

p71_store: ; ( c reg -- )
    mov edx, 0x71   ; db 0xBA dd 0x71
    OUT DX, AL      ; db 0xEE
    _DROP_
    _DROP_
    ret

rtc_fetch_: ; ( reg -- c )
    mov edx, 0x70   ; db 0xBA dd 0x70
    OUT DX, AL      ; db 0xEE
    mov edx, 0x71   ; db 0xBA dd 0x71
    IN AL, DX       ; db 0xEC
    ret

rtc_store_: ; ( c reg -- )
    mov edx, 0x70   ; db 0xBA dd 0x70
    OUT DX, AL      ; db 0xEE
    mov edx, 0x71   ; db 0xBA dd 0x71
    _DROP_
    OUT DX, AL      ; db 0xEE
    _DROP_
    ret

rtc_hi:      ; ( -- ) wait for the RTC second pulse to go high
    _DUP_
    .back:
    mov _TOS_, 10   ; Update in progress" flag (bit 7 of Status Register A).
    call rtc_fetch_
    and al, 0x80
    jz .back
    _DROP_
    ret

rtc_lo:      ; ( -- ) wait for the RTC second pulse to go low
    _DUP_
    .back:
    mov _TOS_, 10   ; Update in progress" flag (bit 7 of Status Register A).
    call rtc_fetch_
    and al, 0x80
    jnz .back
    _DROP_
    ret

get_proc_clk: ; ( -- d ) get the processor clock counter
    _DUP_
    RDTSC           ; Read Time-Stamp Counter
https://c9x.me/x86/html/file\_module\_x86\_id\_278.html
    _DUP_
    mov _TOS_, edx   ; put the high cell in TOS
    ret

calck_:      ; ( -- ) calibrate the ms counter clock
    call rtc_hi      ; wait for the RTC second pulse to go high
    call rtc_lo      ; wait for the RTC second pulse to go low
    call get_proc_clk
    call d_negate_    ; so the d_plus_ later subtracts this value
    call rtc_hi      ; wait for the RTC second pulse to go high
    call rtc_lo      ; wait for the RTC second pulse to go low
    call get_proc_clk
    call d_plus_      ; double number "subtract"

```

```

    mov [ v_onesec ], _TOS_
    mov _SCRATCH_, [ esi ]
    mov [ v_onesec + 4 ], _SCRATCH_ ; put the result in onesec
    ret

ms_:      ; ( n -- )    delay n milli seconds
    _DROP_
    ret

onesec_:  ; ( -- a )    return the address of the onesec variable
    _DUP_
    LOAD_RELATIVE_ADDRESS v_onesec ;
    ret

khz_:     ; ( -- a )    return the address of the khz variable
    _DUP_
    LOAD_RELATIVE_ADDRESS v_khz ;
    ret

font_:    ; ( -- n )    return the address of the font pointer
    _DUP_
    LOAD_RELATIVE_ADDRESS v_font ; font16x24
    ret

last:     ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_last
    ret

blk_:     ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_blk
    ret

seeb:     ; ( -- )      \ toggle the display of blue words in the editor
    not byte [ v_seeb ]
    ret

colourBlindModeToggle: ; ( -- )      \ toggle the editor display colorForth / ANS style
    not byte [ v_colourBlindMode ]
    ret

curs:     ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_curs
    ret

; analyse stack usage
; the stack areas are initialised to all 'U's at power up
; areas of 8 bytes that re not all 'U's are marked by a byte in a 512 byte buffer
; analyse_eight_bytes:  ; ( a -- a' )    zero flag is true if all 'U's
;     xor edx, edx
;     cmp dword [ _TOS_ ], 0x55555555
;     jz .forward
;     inc edx      ; not all 'U's
;     .forward:
;     inc dword _TOS_ ; next address
;     cmp dword [ _TOS_ ], 0x55555555
;     jz .forward2
;     inc edx      ; not all 'U's
;     .forward2:
;     inc dword _TOS_ ; next address
;     add edx, 0
;     ret

analyse_stacks:
    mov _TOS_, STACK_MEMORY_START
    mov _SCRATCH_, STACK_ANALYSIS_BUFFER
    mov ecx, ( TOTAL_STACK_SIZE / 8 ) ; 0x200
    .back:

```



```

        ; call analyse_eight_bytes
        xor edx, edx
        cmp dword [ _TOS_ ], 0x55555555
        jz .forward
        inc edx      ; not all 'U's
        .forward:
        add _TOS_, 4      ; next address
        cmp dword [ _TOS_ ], 0x55555555
        jz .forward2
        inc edx      ; not all 'U's
        .forward2:
        add _TOS_, 4      ; next address
        add edx, 0

        jz .forward3
        mov byte [ _SCRATCH_ ], 0x2E
        jmp .forward4
        .forward3:
        mov byte [ _SCRATCH_ ], 0x55
        .forward4:
        inc _SCRATCH_      ; next address in the results buffer
    loop .back
    ret

stacks_:      ; ( -- a n )
    call analyse_stacks
    _DUP_
    mov _TOS_, STACK_ANALYSIS_BUFFER
    ret
    _DUP_
    mov _TOS_, STACK_MEMORY_START
    _DUP_
    mov _TOS_, TOTAL_STACK_SIZE
    ret

%if 0
stacks_:      ; ( -- a ) \ return the address of the stack memory information ( see v_stack_info for
details )
;RETURN_STACK_SIZE
;DATA_STACK_SIZE
;STACK_MEMORY_START      ; bottom of stack memory
;TOTAL_STACK_SIZE
    _DUP_
    mov _TOS_, RETURN_STACK_0 - 0x3C      ; top of task 0 return stack
    _DUP_
    mov _TOS_, DATA_STACK_0 - 0x3C      ; top of task 0 data stack
    _DUP_
    mov _TOS_, RETURN_STACK_1 - 0x3C      ; top of task 1 return stack
    _DUP_
    mov _TOS_, DATA_STACK_1 - 0x3C      ; top of task 1 data stack
    _DUP_
    mov _TOS_, RETURN_STACK_2 - 0x3C      ; top of task 2 return stack
;    _DUP_
;    mov _TOS_, DATA_STACK_2 - 0x3C      ; top of task 2 data stack
;    LOAD_RELATIVE_ADDRESS v_stack_info
    ret
%endif

ekt:      ; ( -- a ) ; editor key table - variable containing vectors for editor keys beginning with null
; and the shift keys. Then follows right hand top, middle, bottom rows,
; and left hand top, middle, bottom rows. (from ColorForth2.0a.doc)
    _DUP_
    LOAD_RELATIVE_ADDRESS editorActionTable
    ret

vword_:      ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_words
    ret

```

```

;vregs_:  ; ( -- a )
;  _DUP_
;  mov eax, V_REGS
;  ret

ivec_:  ; ( -- a )
;  _DUP_
;  mov eax, INTERRUPT_VECTORS
;  ret

pic_:  ; ( -- a )
;  _DUP_
;  mov eax, IDT_AND_PIC_SETTINGS
;  ret

```

```
%if 0
```

From : <https://pdos.csail.mit.edu/6.828/2014/readings/hardware/8259A.pdf>

The following registers can be read via OCW3 (IRR and ISR or OCW1 [IMR]).

Interrupt Request Register (IRR):

8-bit register which contains the levels requesting an interrupt to be acknowledged.

The highest request level is reset from the IRR when an interrupt is acknowledged. (Not affected by IMR.)

In-Service Register (ISR):

8-bit register which contains the priority levels that are being serviced.

The ISR is updated when an End of Interrupt Command is issued.

Interrupt Mask Register:

8-bit register which contains the interrupt request lines which are masked.

The IRR can be read when, prior to the RD pulse, a Read Register Command is issued with OCW3 (RR = 1, RIS = 0.)

The ISR can be read, when, prior to the RD pulse, a Read Register Command is issued with OCW3 (RR = 1, RIS = 1).

There is no need to write an OCW3 before every status read operation,

as long as the status read corresponds with the previous one; i.e., the 8259A 'remembers' whether the IRR or ISR has been previously selected by the OCW3.

This is not true when poll is used.

After initialization the 8259A is set to IRR.

For reading the IMR, no OCW3 is needed.

The output data bus will contain the IMR whenever RD is active and A0 = 1 (OCW1).

Polling overrides status read when P = 1, RR = 1 in OCW3.

From : https://en.wikibooks.org/wiki/X86_Assembly/Programmable_Interrupt_Controller

Remapping

Another common task, often performed during the initialization of an operating system, is remapping the PICs.

That is, changing their internal vector offsets, thereby altering the interrupt numbers they send.

The initial vector offset of PIC1 is 8, so it raises interrupt numbers 8 to 15.

Unfortunately, some of the low 32 interrupts are used by the CPU for exceptions

(divide-by-zero, page fault, etc.), causing a conflict between hardware and software interrupts.

The usual solution to this is remapping the PIC1 to start at 32, and often the PIC2 right after it at 40.

This requires a complete restart of the PICs, but is not actually too difficult, requiring just eight 'out's.

```

mov al, 0x11
out 0x20, al          ; restart PIC1
out 0xA0, al          ; restart PIC2

mov al, 0x20
out 0x21, al          ; PIC1 now starts at 32
mov al, 0x28
out 0xA1, al          ; PIC2 now starts at 40

mov al, 3
out 0x21, al          ; setup cascading
mov al, 0x02

```

```

out 0xA1, al

mov al, 0x01
out 0x21, al
out 0xA1, al                ;done!

From: cf2019 Forth block 244
: p!   pc! ; \ 8 bit port store
: pic1! $21 p! ;
: pic2! $A1 p! ;

: !pic cli
( init )      $11 dup $20 p! $A0 p!
( irq )       $20 pic1! $28 pic2!
( master )    #4 pic1!
( slave )     #2 pic2!
( 8086 mode ) #1 dup pic1! pic2!
( mask irqs ) $FF pic2! $FA pic1! ;

Re-factored :
: !pic cli
\ PIC1
( init )      $11 $20 p!
( irq )       $20 $21 p!
( master )    $04 $21 p!
( 8086 mode ) $01 $21 p!
( mask irqs ) $FA $21 p!
\ PIC2
( init )      $11 $A0 p!
( irq )       $28 $A1 p!
( slave )     $02 $A1 p!
( 8086 mode ) $01 $A1 p!
( mask irqs ) $FF $A1 p!
;

%endif

dap_:   ; ( -- a )
    _DUP_
    mov eax, DAP_BUFFER
    ret

sect_:   ; ( -- a )
    _DUP_
    mov eax, SECTOR_BUFFER
    ret

digin:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_digin
    ret

actc:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS actionColourTable
    ret

tickh:   ; ( -- a )    HERE variable address
    _DUP_
    LOAD_RELATIVE_ADDRESS v_H
    ret

forths_: ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_ForthWordCount
    ret

macros_: ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_MacroWordCount

```

```

    ret

offset_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_offset
    ret

vesa:      ; ( -- a )
    _DUP_
    mov _TOS_, VESA_BUFFER
    ret

vesamode_: ; ( -- u )
    _DUP_
    xor _TOS_, _TOS_
    mov word ax, [ vesa_SavedMode ]    ; the saved VESA video mode value
    ret

fetchDX_:  ; ( -- c )
    _DUP_
    xor _TOS_, _TOS_
    push edi
    mov edi, DAP_BUFFER
    mov _TOS_1_, [ edi + o_Int13_DAP_saved_DX ]    ; setup DX value returned by the BIOS
    pop edi
    ret

trash_:    ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_trash
    ret

buffer_:   ; ( -- a )
    _DUP_
    mov _TOS_, SECTOR_BUFFER ;0x25300
    ret

cad:       ; ( -- a ) \ the address of the cursor as an offset from the start of the currently displayed
block
    _DUP_
    LOAD_RELATIVE_ADDRESS v_cad
    ret

pcad:      ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_pcad
    ret

; hsvv_:   ; ( -- a )
;
;     _DUP_
;     LOAD_RELATIVE_ADDRESS hsvv
;     ret

displ:     ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS displayShannonFanoActions
    ret

cBlindAddr_: ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS x_colourBlind
    ret

; *****
; memory operators
; *****

cFetch_:   ; ( a -- c ) \ c@
    xor _SCRATCH_, _SCRATCH_
    mov byte _SCRATCH_1_, [ _TOS_ ] ;

```

```

    mov _TOS_, _SCRATCH_
    ret

wFetch_:      ; ( a -- w ) \ w@
    xor _SCRATCH_, _SCRATCH_
    mov word _SCRATCH_x_, [ _TOS_ ] ;
    mov _TOS_, _SCRATCH_
    ret

fetch_:       ; ( a -- u ) \ @
    mov dword _TOS_, [ _TOS_ ] ;
    ret

two_fetch_:   ; ( a -- x1 x2 )
    sub esi, 4                                ; make room on stack
    mov _SCRATCH_, [ _TOS_ + 4 ]             ; read x1 from addr+4
    mov [ esi ], _SCRATCH_                   ; write onto stack
    mov _TOS_, [ _TOS_ ]                     ; read x2 from addr+0, replacing tos
    ret

cStore_:      ; ( c a -- ) \ c!
    mov _SCRATCH_, [ esi ]
    mov byte [ _TOS_ ], _SCRATCH_1_
    ret

wStore_:      ; ( w a -- ) \ w!
    mov _SCRATCH_, [ esi ]
    mov word [ _TOS_ ], _SCRATCH_x_
    ret

store_:       ; ( u a -- ) \ !
    mov _SCRATCH_, [ esi ]
    mov dword [ _TOS_ ], _SCRATCH_
    ret

two_store_:   ; ( x1 x2 a -- ) \ 2!
    mov _SCRATCH_, [ _TOS_ ]                 ;
    mov ecx, [ esi + 4 ]                     ; x1 into ecx
    mov [ _TOS_ ], _SCRATCH_                 ; write x2 to addr+0
    mov [ _TOS_ + 4 ], ecx                   ; and x1 to addr+4
    mov _TOS_, [ esi + 8 ]                   ; read new TOS
    add esi, 12                              ; drop the stack
    ret

plus_store_:  ; ( n addr -- ) \ +!
    mov _SCRATCH_, [ esi ]                   ; copy the value n into the scratch register
    add _SCRATCH_, [ _TOS_ ]                 ; add to value at addr
    mov _TOS_, [ esi + 4 ]                   ; refresh tos
    add esi, 8                               ; drop the stack
    ret

; *****
; double number operators
; *****

d_negate_:   ; ( d1 -- d2 )
    not dword [ esi ]                       ; invert d1-lo
    not _TOS_                               ; invert d1-hi
    add dword [ esi ], 1                     ; make two's complement
    adc _TOS_, 0                             ; from invert + 1
    ret

d_plus_:     ; ( d1 d2 -- d3 ) add d2 to d1 to give d3
    mov _SCRATCH_, [ esi ]                  ; get d2-lo
    add _SCRATCH_, [ esi + 8 ]               ; add d1-lo
    adc _TOS_, [ esi + 4 ]                   ; add d1-hi and carry to d2-hi
    mov [ esi + 8 ], _SCRATCH_               ; write d3-low
    add esi, 8                              ; and clean up stack
    ret

```

```

d_minus_:    ; ( d1 d2 -- d3 )    subtract d2 from d1 to give d3
    call d_negate_
    call d_plus_
    ret

; *****
; stack operators
; *****

two_dup_:    ; ( a b -- a b a b )
;    sub esi, byte 0x08 ; lea esi, [ esi - 0x08 ]    ; pre-decrement the stack pointer, adding 2 cells
;    mov [ esi + 4 ], _TOS_    ; copy x2 to Third On Stack ( second on the real stack )
;    mov _SCRATCH_, [ esi + 8 ]    ; copy x1 to register ebx
;    mov [ esi ], _SCRATCH_    ; copy register ebx to Fourth On Stack
    _OVER_
    _OVER_
    ret

two_drop_:    ; ( a b -- )
    _DROP_
    _DROP_
    ret

two_swap_:    ; ( a b c d -- c d a b )
    mov _SCRATCH_, [ esi + 8 ]
    xchg _SCRATCH_, [ esi ]
    mov [ esi + 8 ], _SCRATCH_
    xchg _TOS_, [ esi + 4 ]
    ret

two_over_:    ; ( a b c d -- a b c d a b )
    lea esi, [ esi - 8 ]
    mov [ esi + 4 ], _TOS_
    mov _SCRATCH_, [ esi + 0x10 ]
    mov [esi], _SCRATCH_
    mov _TOS_, [ esi + 0x0C ]
    ret

rot_:    ; ( a b c -- b c a )
    mov _SCRATCH_, [ esi + 4 ]
    mov ebp, [ esi ]
    mov [ esi + 4 ], ebp
    mov [ esi ], _TOS_
    mov _TOS_, _SCRATCH_
    ret

minus_rot_:    ; -rot ( a b c -- c b a )
    mov _SCRATCH_, [ esi + 4 ]
    mov ebp, [ esi ]
    mov [ esi + 4 ], _TOS_
    mov [esi], _SCRATCH_
    mov _TOS_, ebp
    ret

tuck_:    ; ( a b -- b a b )
    _SWAP_
    _OVER_
    ret

pick_:    ; ( ... n -- ... u ) where u is the n'th stack item
    mov eax, [ esi + ( eax * 4 ) ]
    ret

#define CELL_WIDTH 0x04    ; this is a 32 bit wide system = 4 bytes

cell_:    ; ( -- c )
    _DUP_
    mov _TOS_, CELL_WIDTH
    ret

```

```

cell_minus_:    ; ( u -- u' )
               sub _TOS_, CELL_WIDTH
               ret

cell_plus_:     ; ( u -- u' )
               add _TOS_, CELL_WIDTH
               ret

cells_:         ; ( u -- u' )
               add _TOS_, _TOS_   ; this code must be changed if CELL_WIDTH is changed
               add _TOS_, _TOS_
               ret

; *****
; save and restore the Interrupt Descriptor Table and Interrupt Mask Registers
; *****

lidt_: ; ( a -- ) \ set a into the Interrupt Descriptor Table (IDT) register
      cli
      push ebp
      mov ebp, ( PIC_BIOS_IDT_SETTINGS ) ; 6 bytes of RAM used to store the IDT info
      mov word [ ebp ], 0x03B7
      mov [ ebp + 2 ], _TOS_ ; save IDT base address from eax
      lidt [ ebp ] ; db 0x0F, 0x01, 0x18
      _DROP_
      pop ebp
      ret

sidt_: ; ( -- a ) \ return the address contained in the Interrupt Descriptor Table (IDT) register
      cli
      _DUP_
      push ebp
      mov ebp, ( IDT_AND_PIC_SETTINGS_PAD ) ; 6 bytes of RAM used to interface to the stack
      sidt [ ebp ] ; write the 6-byte IDT to memory location pointed to by ebp
      mov _TOS_, [ ebp + 2 ] ; save IDT base address to eax
      pop ebp
      ret

save_BIOS_idt: ; ( -- ) \ save the Interrupt Descriptor Table (IDT) register value
      cli
      push ebp
      mov ebp, ( PIC_BIOS_IDT_SETTINGS ) ; 6 bytes of RAM used to save the values in
      sidt [ ebp ] ; write the 6-byte IDT to memory location pointed to by ebp
      pop ebp
      ret

restore_BIOS_idt: ; ( -- ) \ restore the saved IDT value into the Interrupt Descriptor Table (IDT)
register
      cli
      push ebp
      mov ebp, ( PIC_BIOS_IDT_SETTINGS ) ; 6 bytes of RAM used to restore from
      lidt [ ebp ] ; db 0x0F, 0x01, 0x18
      pop ebp
      ret

save_BIOS_idt_and_pic: ; ( -- ) \ save the PIC1 and PIC2 IMR values into IDT_AND_PIC_SETTINGS at startup
      cli
      call save_BIOS_idt
      push ebp
      mov ebp, ( PIC_BIOS_IMR_SETTINGS ) ; 2 bytes of RAM used to save the IMR for PIC1 and PIC2
; PIC1
      in al, 0x21 ; read PIC1's IMR value
      mov [ ebp ], al
; PIC2
      inc ebp
      in al, 0xA1 ; read PIC 2's IMR value
      mov [ ebp ], al
      pop ebp
      ret

```

```

restore_BIOS_idt_and_pic: ; ( -- ) \ restore the saved BIOS PIC and IMR values into PIC1 and PIC2
cli
call restore_BIOS_idt
push ebp
mov ebp, ( PIC_BIOS_IMR_SETTINGS ) ; 2 bytes of RAM used to save the IMR for PIC1 and PIC2
; PIC1
mov al, 0x11 ; init command
out 0x20, al ; init PIC1 ( $11 $20 p! )
mov al, 0x00 ; PIC1 Interrupt Vector table start address
out 0x21, al ; PIC1 now starts at 0x00 ( $00 $21 p! )
mov al, 0x04 ; master mode command
out 0x21, al ; set PIC1 as master, sets up cascading of PIC1 and PIC2 ( $04 $21 p! )
mov al, 0x01 ; 8086 command
out 0x21, al ; set 8086 mode ( $01 $21 p! )
mov al, [ ebp ] ; Interrupt Mask Register ( IMR )
out 0x21, al ; set PIC1's IMR, BIOS = 0xB8 ( $xx $21 p! )
; PIC2
inc ebp
mov al, 0x11 ; init command
out 0xA0, al ; init PIC2
mov al, 0x08 ; PIC2 Interrupt Vector table start address
out 0xA1, al ; PIC2 now starts at 0x08 $08 $A1 p!
mov al, 0x02 ; slave mode command
out 0xA1, al ; set PIC2 as slave ( $02 $A1 p! )
mov al, 0x01 ; 8086 command
out 0xA1, al ; set 8086 mode ( $01 $A1 p! )
mov al, [ ebp ] ; Interrupt Mask Register ( IMR )
out 0xA1, al ; set PIC2's IMR, BIOS = 0x8F ( $xx $A1 p! )
pop ebp
ret

restore_new_idt_and_pic: ; ( -- ) \ restore the new IDT and PIC IMR values
cli
push ebp
mov ebp, ( PIC_NEW_IMR_SETTINGS ) ; 2 bytes of RAM used to save the IMR for PIC1 and PIC2
; PIC1
mov al, 0x11 ; init command
out 0x20, al ; init PIC1 ( $11 $20 p! )
mov al, 0x20 ; PIC1 Interrupt Vector table start address
out 0x21, al ; PIC1 now starts at 0x20 ( $20 $21 p! )
mov al, 0x04 ; master mode command
out 0x21, al ; set PIC1 as master, sets up cascading of PIC1 and PIC2 ( $04 $21 p! )
mov al, 0x01 ; 8086 command
out 0x21, al ; set 8086 mode ( $01 $21 p! )
mov al, [ ebp ] ; Interrupt Mask Register ( IMR )
out 0x21, al ; set PIC1's IMR, BIOS = 0xB8 ( $xx $21 p! )
; PIC2
inc ebp
mov al, 0x11 ; init command
out 0xA0, al ; init PIC2
mov al, 0x28 ; PIC2 Interrupt Vector table start address
out 0xA1, al ; PIC2 now starts at 0x28 $28 $A1 p!
mov al, 0x02 ; slave mode command
out 0xA1, al ; set PIC2 as slave ( $02 $A1 p! )
mov al, 0x01 ; 8086 command
out 0xA1, al ; set 8086 mode ( $01 $A1 p! )
mov al, [ ebp ] ; Interrupt Mask Register ( IMR )
out 0xA1, al ; set PIC2's IMR, BIOS = 0x8F ( $xx $A1 p! )
pop ebp
ret

init_default_PIC_IMRs: ; ( -- )
pushf
cli

pusha
mov esi, 0x0000 ; source address = the BIOS interrupt vector table
mov edi, INTERRUPT_VECTORS ; destination address
mov ecx, ( 1024 / 4 ) ; 1024 bytes in cells

```



```

    rep movsd                      ; does not change AX , it moves DS:SI to ES:DI and increments SI and
DI
    ; now copy Interrupts 0x00 to 0x0F up to 0x20 to 0x2F
    mov esi, 0x0000                ; source address = the BIOS interrupt vector table
    mov edi, ( INTERRUPT_VECTORS + ( 0x20 * 4 ) ) ; destination address
    mov ecx, ( 0x10 )              ; 16 vectors in cells
    rep movsd                      ; does not change AX , it moves DS:SI to ES:DI and increments SI and
DI
    popa

    push ebp
    mov ebp, ( PIC_NEW_IMR_SETTINGS ) ; 2 bytes of RAM used to save the IMR for PIC1 and PIC2
    mov byte [ ebp ], 0xFA          ; Interrupt Mask Register ( IMR ) saved value for PIC1
    inc ebp
    mov byte [ ebp ], 0xFF          ; Interrupt Mask Register ( IMR ) saved value for PIC2
    pop ebp
    popf
    ret

set_PIC1_IMR:    ; ( c -- ) \ set the Interrupt Mask Register for PIC1 and copy to PIC_NEW_IMR_SETTINGS
    pushf
    cli
    push ebp
    mov ebp, ( PIC_NEW_IMR_SETTINGS ) ; 1 byte of RAM used to save the IMR for PIC1
    mov [ ebp ], al                ; Interrupt Mask Register ( IMR )
    out 0x21, al                   ; set PIC1's IMR ( $xx $21 p! )
    pop ebp
    popf
    _DROP_
    ret

set_PIC2_IMR:    ; ( c -- ) \ set the Interrupt Mask Register for PIC2 and copy to PIC_NEW_IMR_SETTINGS+1
    pushf
    cli
    push ebp
    mov ebp, ( PIC_NEW_IMR_SETTINGS + 1 ) ; 1 byte of RAM used to save the IMR for PIC1
    mov [ ebp ], al                ; Interrupt Mask Register ( IMR )
    out 0xA1, al                   ; set PIC2's IMR ( $xx $A1 p! )
    pop ebp
    popf
    _DROP_
    ret

; *****
; lp support for GGraphics demo
; *****

lp_:
;; test what lodsd actually does
;   push esi
;   mov esi, [ v_trash ]          ; setup EDI to point to the current trash buffer address
;   mov [ v_lcad ], esi
;   lodsd ; loads a 32 bit dword from [ds:esi] into _TOS_, increments esi by 4 : true
;   mov [ v_pcad ], esi
;   pop esi
;   _DUP_
;   mov _TOS_, [ v_lcad ]
;   _DUP_
;   mov _TOS_, [ v_pcad ]
;   ret
;   nop
;   nop
;   nop
db 0x8B , 0xE8 ; mov ebp,eax
lodsd ; loads a 32 bit dword from [ds:esi] into _TOS_, increments esi by 4
db 0x8B , 0xC8 ; mov ecx,eax
lodsd ; loads a 32 bit dword from [ds:esi] into _TOS_, increments esi by 4
mov ebx,[edx+0x20]
.back:

```

```

    mov [ebx],bp
    db 0x23 , 0xC0 ; and eax,eax    21C0          and eax,eax
    js .forward
    add eax,[edx]
    add ebx,[edx+0x18]
    .forward:
    add eax,[edx+0x8]
    add ebx,[edx+0x10]
    loop .back
;    dd 0x8B909090 , 0xC88BADE8 , 0x205A8BAD , 0x232B8966
;    dd 0x030578C0 , 0x185A0302 , 0x03084203 , 0xECE2105A
    ret

; *****
; maths operators
; The ANSI/ISO Forth Standard (adopted in 1994) mandates the minimal set
; of arithmetic operators + - * / MOD */ /MOD */MOD and M* .
; *****

two_slash_:                                ; ( n -- n' )    "2/" arithmetic divide by 2
    sar _TOS_, 0x01
    ret

u_two_slash_:                             ; ( u -- u' )    "u2/" unsigned divide by 2
    shr _TOS_, 0x01
    ret

rshift_:                                  ; ( u c -- u' )    shift TOS right by c bits
    mov ecx, _TOS_
    _DROP_
    shr _TOS_, cl
    ret

lshift_:                                  ; ( u c -- u' )    shift TOS left by c bits
    mov ecx, _TOS_
    _DROP_
    shl _TOS_, cl
    ret

%if 0
; untested!!!
mod_:                                      ; ( n1 n2 -- n3 )
    mov _TOS_, [ esi ]                    ; get dividend
    cdq                                    ; sign extend dividend
    idiv _SCRATCH_                         ; do the divide
    add esi, 4                             ; clean up stack
    mov _TOS_, edx                         ; and return remainder in tos
    ret

%endif

; "idiv ecx" divides the signed double dividend EDX:EAX, by the divisor in ECX
; and stores the remainder in EDX and quotient in EAX
slash_mod_:                               ; /mod ( n1 n2 -- r q )
    mov ecx, _TOS_                         ; get n2 the divisor
    mov _TOS_, [ esi ]                     ; get n1 the dividend
    cdq                                    ; sign extend into edx
    idiv ecx                               ; do the divide
    mov [ esi ], edx                       ; and remainder to stack
    ret

; "imul ecx" multiplies ECX by EAX and stores the result in EDX:EAX
; ToDo: fix and test this properly...
star_slash_mod_:                          ; */mod ( n1 n2 n3 -- r q )
    push _TOS_
    mov ecx, [ esi ]                       ; get n2
    mov _TOS_, [ esi + 4 ]                 ; get n1
    imul ecx                               ; n1*n2 => edx:eax
    add esi, 4                             ; clean up stack
    pop ecx
    idiv ecx                               ; n1*n2/n3

```

```

    mov [ esi ], edx          ; remainder to stack
    ret

star_slash_:                  ; */ ( n1 n2 n3 -- n )
    push _TOS_
    mov ecx, [ esi ]          ; get n2
    mov _TOS_, [ esi + 4 ]    ; get n1
    imul ecx                  ; n1*n2 => edx:eax
    add esi, 8                ; clean up stack
    pop ecx
    idiv ecx                  ; n1*n2/n3
    ret

; U*/ is an unsigned */ with the twist of rounding up
; It adds one less than the divisor ( u3 ) to the dividend before dividing
; ToDo: fix and test this properly...
u_star_slash_:                ; U*/ ( u1 u2 u3 -- u )
    mov _SCRATCH_, _TOS_
    dec _SCRATCH_             ; divisor
    mov ecx, [ esi ]          ; get n2
    mov edx, [ esi + 4 ]      ; get n1
    mul ecx                   ; u1 * u2
    add _TOS_, _SCRATCH_      ; round up
    adc edx, 0                ;
    inc _SCRATCH_             ; restore the original u3 divisor
    div _SCRATCH_             ; do the division
    add esi, 8                ; clean up stack
    ret

cmove_:                        ; ( from to count -- )
    test _TOS_, _TOS_
    jz .forward
    mov _SCRATCH_, _TOS_
    mov edx, [ esi + 0 ]
    mov ecx, [ esi + 0x04 ]
    .back:
        mov byte al, [ ecx + 0 ]
        mov byte [ edx + 0 ], al
        inc ecx
        inc edx
        dec _SCRATCH_
    jnz .back
    .forward:
    mov _TOS_, [ esi + 0x08 ]
    add esi, 0x0C
    ret

two_star_:                     ; 2* ( u -- u' )    u' = 2 * u
    shl _TOS_, 1
    ret

two_star_star_:                ; 2** ( c -- u )    u = 2 ** c
    mov ecx, _TOS_
    mov eax, 0x00000001
    shl _TOS_, cl
    ret

; *****
; Random and Pseudo Random Number Generators
; *****

GetCPUIDsupport:               ; ( -- ) equal flag is set if no CPUID support
    ; check to see if CPUID is supported
    pushfd                    ; save EFLAGS
    pop eax                   ; store EFLAGS in EAX
    mov ebx, eax              ; save in EBX for later testing
    xor eax, 00200000h        ; toggle bit 21
    push eax                  ; push to stack
    popfd                     ; save changed EAX to EFLAGS
    pushfd                    ; push EFLAGS to TOS

```

```

    pop eax                ; store EFLAGS in EAX
    cmp eax, ebx           ; see if bit 21 has changed
    ret

GetRDRANDsupport:         ; zero flag is set if no support for RDRAND, the hardware Random Number generator
    mov eax, 0x00000001    ; select the 'features' CPU information
    CPUID                  ; get CPU information into eax, ebx, ecx and edx
    test eax, 0x40000000 ; Bit 30 of ECX returned by CPUID => RDRAND present if true
    ret

GetCPUID_:                ; ( -- u )
    _DUP_
    mov eax, 0x00000001    ; select the 'features' CPU information
    CPUID                  ; get CPU information into eax, ebx, ecx and edx
    ret

rdtsc_:                   ; ( -- u ) \ return the current processor instruction counter
    _DUP_
    rdtsc ; db 0x0F, 0x31
    ret

randInit_:
    call rdtsc_
    push ebp
    mov ebp, v_random
    xor [ ebp ], _TOS_     ; vRandom ! , if the value was 0
    pop ebp
    _DROP_
    ret

%if 0
\ Marsaglia, "Xorshift RNGs". http://www.jstatsoft.org/v08/i14/paper
: Random32 ( -- u )
    vRandom @
    dup 0= or
    dup 6 lshift xor
    dup 21 rshift xor
    dup 7 lshift xor
    dup vRandom ! ;
%endif

; \ Marsaglia, "Xorshift RNGs". http://www.jstatsoft.org/v08/i14/paper
getRandMarsaglia: ; ( -- u ) \ load a 32 bit pseudo random number into TOS
    _DUP_
    push ebp
    mov ebp, v_random
    mov _TOS_, [ ebp ]    ; vRandom @
    test _TOS_, _TOS_
    jnz .forward
    mov _TOS_, 0xFFFFFFFF
    .forward:

    mov _SCRATCH_, _TOS_  ; dup 6 lshift xor
    shl _SCRATCH_, 0x06
    xor _TOS_, _SCRATCH_

    mov _SCRATCH_, _TOS_  ; dup 21 rshift xor
    shr _SCRATCH_, 0x15
    xor _TOS_, _SCRATCH_

    mov _SCRATCH_, _TOS_  ; dup 7 lshift xor
    shl _SCRATCH_, 0x07
    xor _TOS_, _SCRATCH_

    mov [ ebp ], _TOS_    ; vRandom !

    pop ebp
    ret

rand_:                   ; ( -- u ) \ load a 32 bit true random number into TOS

```

```

    _DUP_
    call GetCPUIDsupport
    je .NO_CPUID          ; if no change to bit 21, no CPUID
    ; CPUID is supported, so check if RDRAND is supported
    call GetRDRANDsupport
    jz .NO_CPUID          ; test for RDRAND support
    RDRAND _TOS_          ; supported, so call the instruction
    ret
.NO_CPUID:
    _DROP_
    call getRandMarsaglia
    ret

randq_:      ; ( -- f ) \ returns true if the processor supports the RDRAND random number instruction
    _DUP_
    call GetCPUIDsupport
    jz .NO_CPUID          ; if no change, no CPUID
    ; CPUID is supported, so check if RDRAND is supported
    call GetRDRANDsupport
    jz .NO_CPUID          ; test for RDRAND support
    mov _TOS_, 0xFFFFFFFF
    ret
.NO_CPUID:
    xor _TOS_, _TOS_
    ret

; *****
; CRC32 Cyclic Redundancy Checksum (32 bit)
; The International Standard 32-bit cyclical redundancy check defined by :
; [ITU-T-V42] International Telecommunications Union, "Error-correcting
; Procedures for DCEs Using Asynchronous-to-Synchronous Conversion",
; ITU-T Recommendation V.42, 1994, Rev. 1.
; and
; [ISO-3309]
; International Organization for Standardization,
; "Information Processing Systems--Data Communication High-Level Data Link
; Control Procedure--Frame Structure", IS 3309, October 1984, 3rd Edition.
; *****

crc32_table:
    dd 00000000h, 077073096h, 0EE0E612Ch, 0990951BAh, 0076DC419h, 0706AF48Fh, 0E963A535h, 09E6495A3h,
    00EDB8832h, 079DCB8A4h
    dd 0E0D5E91Eh, 097D2D988h, 009B64C2Bh, 07EB17CBDh, 0E7B82D07h, 090BF1D91h, 01DB71064h, 06AB020F2h,
    0F3B97148h, 084BE41DEh
    dd 01ADAD47Dh, 06DDDE4EBh, 0F4D4B551h, 083D385C7h, 0136C9856h, 0646BA8C0h, 0FD62F97Ah, 08A65C9ECh,
    014015C4Fh, 063066CD9h
    dd 0FA0F3D63h, 08D080DF5h, 03B6E20C8h, 04C69105Eh, 0D56041E4h, 0A2677172h, 03C03E4D1h, 04B04D447h,
    0D20D85FDh, 0A50AB56Bh
    dd 035B5A8FAh, 042B2986Ch, 0DBB8C9D6h, 0ACBCF940h, 032D86CE3h, 045DF5C75h, 0DCD60DCFh, 0ABD13D59h,
    026D930ACh, 051DE003Ah
    dd 0C8D75180h, 0BFD06116h, 021B4F4B5h, 056B3C423h, 0CFBA9599h, 0B8BDA50Fh, 02802B89Eh, 05F058808h,
    0C60CD9B2h, 0B10BE924h
    dd 02F6F7C87h, 058684C11h, 0C1611DABh, 0B6662D3Dh, 076DC4190h, 001DB7106h, 098D220BCh, 0EFD5102Ah,
    071B18589h, 006B6B51Fh
    dd 09FBFE4A5h, 0E8B8D433h, 07807C9A2h, 00F00F934h, 09609A88Eh, 0E10E9818h, 07F6A0DBBh, 0086D3D2Dh,
    091646C97h, 0E6635C01h
    dd 06B6B51F4h, 01C6C6162h, 0856530D8h, 0F262004Eh, 06C0695EDh, 01B01A57Bh, 08208F4C1h, 0F50FC457h,
    065B0D9C6h, 012B7E950h
    dd 08BBEB8EAh, 0FCB9887Ch, 062DD1DDFh, 015DA2D49h, 08CD37CF3h, 0FBD44C65h, 04DB26158h, 03AB551CEh,
    0A3BC0074h, 0D4BB30E2h
    dd 04ADFA514h, 03DD895D7h, 0A4D1C46Dh, 0D3D6F4FBh, 04369E96Ah, 0346ED9FCh, 0AD678846h, 0DA60B8D0h,
    044042D73h, 033031DE5h
    dd 0AA0A4C5Fh, 0DD0D7CC9h, 05005713Ch, 0270241AAh, 0BE0B1010h, 0C90C2086h, 05768B525h, 0206F85B3h,
    0B966D409h, 0CE61E49Fh
    dd 05EDEF90Eh, 029D9C998h, 0B0D09822h, 0C7D7A8B4h, 059B33D17h, 02EB40D81h, 0B7BD5C3Bh, 0C0BA6CADh,
    0EDB88320h, 09ABFB3B6h
    dd 003B6E20Ch, 074B1D29Ah, 0EAD54739h, 09DD277AFh, 004DB2615h, 073DC1683h, 0E3630B12h, 094643884h,
    00D6D6A3Eh, 07A6A5AA8h
    dd 0E40ECF0Bh, 09309FF9Dh, 00A00AE27h, 07D079EB1h, 0F00F9344h, 08708A3D2h, 01E01F268h, 06906C2FEh,
    0F762575Dh, 0806567CBh

```

```

    dd 0196C3671h, 06E6B06E7h, 0FED41B76h, 089D32BE0h, 010DA7A5Ah, 067DD4ACCh, 0F9B9DF6Fh, 08EBEEFF9h,
    017B7BE43h, 060B08ED5h
    dd 006D6A3E8h, 0A1D1937Eh, 038D8C2C4h, 04FDDFF252h, 0D1BB67F1h, 0A6BC5767h, 03FB506DDh, 048B2364Bh,
    0D80D2BDAh, 0AF0A1B4Ch
    dd 036034AF6h, 041047A60h, 0DF60EFC3h, 0A867DF55h, 0316E8EEFh, 04669BE79h, 0CB61B38Ch, 0BC66831Ah,
    0256FD2A0h, 05268E236h
    dd 0CC0C7795h, 0BB0B4703h, 0220216B9h, 05505262Fh, 0C5BA3BBEh, 0B2BD0B28h, 02BB45A92h, 05CB36A04h,
    0C2D7FFA7h, 0B5D0CF31h
    dd 02CD99E88h, 05BDEAE1Dh, 09B64C2B0h, 0EC63F226h, 0756AA39Ch, 0026D930Ah, 09C0906A9h, 0EB0E363Fh,
    072076785h, 005005713h
    dd 095BF4A82h, 0E2B87A14h, 07BB12BAEh, 00CB61B38h, 092D28E9Bh, 0E5D5BE0Dh, 07CDCEFB7h, 00BDBDF21h,
    086D3D2D4h, 0F1D4E242h
    dd 068DDB3F8h, 01FDA836Eh, 081BE16CDh, 0F6B9265Bh, 06FB077E1h, 018B74777h, 088085AE6h, 0FF0F6A70h,
    066063BCAh, 011010B5Ch
    dd 08F659EFFh, 0F862AE69h, 0616BFFD3h, 0166CCF45h, 0A00AE278h, 0D70DD2EEh, 04E048354h, 03903B3C2h,
    0A7672661h, 0D06016F7h
    dd 04969474Dh, 03E6E77DBh, 0AED16A4Ah, 0D9D65ADCh, 040DF0B66h, 037D83BF0h, 0A9BCAE53h, 0DEBB9EC5h,
    047B2CF7Fh, 030B5FFE9h
    dd 0BDBDF21Ch, 0CABAC28Ah, 053B39330h, 024B4A3A6h, 0BAD03605h, 0CDD70693h, 054DE5729h, 023D967BFh,
    0B3667A2Eh, 0C4614AB8h
    dd 05D681B02h, 02A6F2B94h, 0B40BBE37h, 0C30C8EA1h, 05A05DF1Bh, 02D02EF8Dh

```

```
; CRC-32 with polynomial $04c11db7, as specified in IEEE 802.3 ( Ethernet )
```

```
crc32_ : ( a n -- u ) \ CRC32 Cyclic Redundancy Checksum
```

```
    push    _SCRATCH_
```

```
    push    ecx
```

```
    push    edx
```

```
    mov     ecx, _TOS_
```

```
    _DROP_
```

```
    mov     _SCRATCH_, _TOS_
```

```
    ; address in ebx, count in ecx, result in eax
```

```
    xor     edx, edx
```

```
    mov     _TOS_, 0xFFFFFFFF ; initial CRC value
```

```
    test    ecx, ecx
```

```
    jz      .forward
```

```
    .back:
```

```
    mov     dl, byte [ _SCRATCH_ ]
```

```
    xor     dl, al
```

```
    shr     _TOS_, 8
```

```
    xor     _TOS_, dword [ crc32_table + ( 4 * edx ) ]
```

```
    inc     _SCRATCH_
```

```
    dec     ecx
```

```
    jnz     .back
```

```
    not     _TOS_ ; invert the final CRC value
```

```
    .forward:
```

```
    pop     edx
```

```
    pop     ecx
```

```
    pop     _SCRATCH_
```

```
    ret
```

```
; *****
; MD5
; *****
```

```
; From : https://github.com/rwfp1/rewolf-md5/blob/master/nasm/rewolf\_md5.inc
```

```

;-----
;|                               The MD5 Message-Digest Algorithm                               |
;-----
;| Description:                                                           |
;| =====                                                             |
;|                               |                                         |
;| The MD5 algorithm is designed to be quite fast on 32-bit machines. In |
;|                               |                                         |

```

```

; addition, the MD5 algorithm does not require any large substitution
; tables, the algorithm can be coded quite compactly.
;
; The MD5 algorithm is an extension of the MD4 message-digest algorithm
; 1,2]. MD5 is slightly slower than MD4, but is more "conservative" in
; design. MD5 was designed because it was felt that MD4 was perhaps
; being adopted for use more quickly than justified by the existing
; critical review, because MD4 was designed to be exceptionally fast,
; it is "at the edge" in terms of risking successful cryptanalytic
; attack. MD5 backs off a bit, giving up a little in speed for a much
; greater likelihood of ultimate security. It incorporates some
; suggestions made by various reviewers, and contains additional
; optimizations. The MD5 algorithm is being placed in the public domain
; for review and possible adoption as a standard.
;
;-----
; Implementation based on rfc1321 (fully rewritten in asm, not ripped :))
;-----
; Usage:
; =====
;
; Simply include this file to your project:
; exp: include \..path..\rewolf_md5.inc
;
; Target compiler...: NASM-YASM
; Calling convention:
;
;         push    size of datablock
;         push    datablock
;         push    destHash
;         call    _rwf_md5
;
; datablock -> (input) -> buffer that contains data to hash
; destHash -> (output) -> 16-bytes buffer for hashed data
;
; Modified registers: none
; Stack is automatically cleared
;
;-----
; Coder.: ReWolf^HTB
; Date..: 17.XII.2004
; E-mail: rewolf@poczta.onet.pl
; WWW...: http://www.rewolf.prv.pl
;-----
; Adaptation for NASM/YASM: Ange Albertini
;-----

```

```

S11 equ 7
S12 equ 12
S13 equ 17
S14 equ 22
S21 equ 5
S22 equ 9
S23 equ 14
S24 equ 20
S31 equ 4
S32 equ 11
S33 equ 16
S34 equ 23
S41 equ 6
S42 equ 10
S43 equ 15
S44 equ 21

%macro FF 7 ;a,b,c,d,k,s,i
    mov edi,%2
    mov ebp,%2
    and edi,%3
    not ebp
    and ebp,%4
    or edi,ebp

```

```

    lea %1, [%1+edi+%7]
    add %1, dword [esi+%5*4]
    rol %1,%6
    add %1,%2
%endmacro

```

```

%macro GG 7
    mov edi,%4
    mov ebp,%4
    and edi,%2
    not ebp
    and ebp,%3
    or  edi,ebp
    lea %1, [%1+edi+%7]
    add %1, dword [esi+%5*4]
    rol %1,%6
    add %1,%2
%endmacro

```

```

%macro HH 7
    mov ebp,%2
    xor ebp,%3
    xor ebp,%4
    lea %1, [%1+ebp+%7]
    add %1, dword [esi+%5*4]
    rol %1,%6
    add %1,%2
%endmacro

```

```

%macro II 7
    mov ebp,%4
    not ebp
    or  ebp,%2
    xor ebp,%3
    lea %1, [%1+ebp+%7]
    add %1, dword [esi+%5*4]
    rol %1,%6
    add %1,%2
%endmacro

```

```

;|      push    size of datablock      |
;|      push    datablock              |
;|      push    destHash                |
md5_:   ; ( a n -- md5_address )
    push _TOS_      ; [ a -- ]
    _DROP_
    push _TOS_ ; [ a n -- ]
    mov _SCRATCH_, MD5_OUTPUT_BUFFER
    push _SCRATCH_ ; [ a n md5_output -- ]
    call _rwf_md5
    mov _TOS_, MD5_OUTPUT_BUFFER
    ret

```

```

_rwf_md5: ; ( a n outputPtr 0 -- )
    pushad
    mov esi,dword [esp+04h+8*4]
    mov dword [esi], 067452301h
    mov dword [esi+04h], 0efcdab89h
    mov dword [esi+08h], 098badcfeh
    mov dword [esi+0Ch], 010325476h
    mov eax,dword [esp+0Ch+8*4]
    push eax
    xor edx,edx
    mov ecx,64
    div ecx
    inc eax
    pop edx
    sub esp,64
    mov ebx,esp
    mov esi,dword [esp+08h+24*4]

```



```

    xchg    eax,edx
_n0:
    mov edi,ebx
    dec edx
    jne _n1
    test eax,eax
    js _nD
    mov byte [ebx+eax],80h
    jmp _nC
_nD:
    xor eax,eax
    dec eax
_nC:
    mov ecx,64
    sub ecx,eax
    add edi,eax
    push eax
    xor eax,eax
    inc edi
    dec ecx
    rep stosb
    pop eax
    test eax,eax
    js _nB
    cmp eax,56
    jnb _nE
_nB:
    push eax
    mov eax,dword [esp+0Ch+25*4]
    push edx
    xor edx,edx
    mov ecx,8
    mul ecx
    mov dword [ebx+56],eax
    mov dword [ebx+60],edx
    pop edx
    pop eax
    jmp _n1
_nE:
    inc edx
_n1:
    test eax,eax
    js _nA
    cmp eax,64
    jnb _n2
    jmp _n10
_nA:
    xor eax,eax
_n10:
    mov ecx,eax
    jmp _n3
_n2:
    mov ecx,64
_n3:
    mov edi,ebx
    rep movsb
    push eax
    push edx
    push ebx
    push esi
    lea esi, [esp+10h]
    mov edi, dword [esp+4+28*4]
    push edi
    mov eax, dword [edi]
    mov ebx, dword [edi+04h]
    mov ecx, dword [edi+08h]
    mov edx, dword [edi+0Ch]

    FF  eax, ebx, ecx, edx, 0, S11, 0d76aa478h
    FF  edx, eax, ebx, ecx, 1, S12, 0e8c7b756h

```

```

FF ecx, edx, eax, ebx, 2, S13, 0242070dbh
FF ebx, ecx, edx, eax, 3, S14, 0c1bdceeeh
FF eax, ebx, ecx, edx, 4, S11, 0f57c0fafh
FF edx, eax, ebx, ecx, 5, S12, 04787c62ah
FF ecx, edx, eax, ebx, 6, S13, 0a8304613h
FF ebx, ecx, edx, eax, 7, S14, 0fd469501h
FF eax, ebx, ecx, edx, 8, S11, 0698098d8h
FF edx, eax, ebx, ecx, 9, S12, 08b44f7afh
FF ecx, edx, eax, ebx, 10, S13, 0ffff5bb1h
FF ebx, ecx, edx, eax, 11, S14, 0895cd7beh
FF eax, ebx, ecx, edx, 12, S11, 06b901122h
FF edx, eax, ebx, ecx, 13, S12, 0fd987193h
FF ecx, edx, eax, ebx, 14, S13, 0a679438eh
FF ebx, ecx, edx, eax, 15, S14, 049b40821h

```

```

GG eax, ebx, ecx, edx, 1, S21, 0f61e2562h
GG edx, eax, ebx, ecx, 6, S22, 0c040b340h
GG ecx, edx, eax, ebx, 11, S23, 0265e5a51h
GG ebx, ecx, edx, eax, 0, S24, 0e9b6c7aah
GG eax, ebx, ecx, edx, 5, S21, 0d62f105dh
GG edx, eax, ebx, ecx, 10, S22, 002441453h
GG ecx, edx, eax, ebx, 15, S23, 0d8a1e681h
GG ebx, ecx, edx, eax, 4, S24, 0e7d3fbc8h
GG eax, ebx, ecx, edx, 9, S21, 021e1cde6h
GG edx, eax, ebx, ecx, 14, S22, 0c33707d6h
GG ecx, edx, eax, ebx, 3, S23, 0f4d50d87h
GG ebx, ecx, edx, eax, 8, S24, 0455a14edh
GG eax, ebx, ecx, edx, 13, S21, 0a9e3e905h
GG edx, eax, ebx, ecx, 2, S22, 0fcefa3f8h
GG ecx, edx, eax, ebx, 7, S23, 0676f02d9h
GG ebx, ecx, edx, eax, 12, S24, 08d2a4c8ah

```

```

HH eax, ebx, ecx, edx, 5, S31, 0fffa3942h
HH edx, eax, ebx, ecx, 8, S32, 08771f681h
HH ecx, edx, eax, ebx, 11, S33, 06d9d6122h
HH ebx, ecx, edx, eax, 14, S34, 0fde5380ch
HH eax, ebx, ecx, edx, 1, S31, 0a4beea44h
HH edx, eax, ebx, ecx, 4, S32, 04bdecfa9h
HH ecx, edx, eax, ebx, 7, S33, 0f6bb4b60h
HH ebx, ecx, edx, eax, 10, S34, 0bebfbf70h
HH eax, ebx, ecx, edx, 13, S31, 0289b7ec6h
HH edx, eax, ebx, ecx, 0, S32, 0eaa127fah
HH ecx, edx, eax, ebx, 3, S33, 0d4ef3085h
HH ebx, ecx, edx, eax, 6, S34, 004881d05h
HH eax, ebx, ecx, edx, 9, S31, 0d9d4d039h
HH edx, eax, ebx, ecx, 12, S32, 0e6db99e5h
HH ecx, edx, eax, ebx, 15, S33, 01fa27cf8h
HH ebx, ecx, edx, eax, 2, S34, 0c4ac5665h

```

```

II eax, ebx, ecx, edx, 0, S41, 0f4292244h
II edx, eax, ebx, ecx, 7, S42, 0432aff97h
II ecx, edx, eax, ebx, 14, S43, 0ab9423a7h
II ebx, ecx, edx, eax, 5, S44, 0fc93a039h
II eax, ebx, ecx, edx, 12, S41, 0655b59c3h
II edx, eax, ebx, ecx, 3, S42, 08f0ccc92h
II ecx, edx, eax, ebx, 10, S43, 0ffe447d4h
II ebx, ecx, edx, eax, 1, S44, 085845dd1h
II eax, ebx, ecx, edx, 8, S41, 06fa87e4fh
II edx, eax, ebx, ecx, 15, S42, 0fe2ce6e0h
II ecx, edx, eax, ebx, 6, S43, 0a3014314h
II ebx, ecx, edx, eax, 13, S44, 04e0811a1h
II eax, ebx, ecx, edx, 4, S41, 0f7537e82h
II edx, eax, ebx, ecx, 11, S42, 0bd3af235h
II ecx, edx, eax, ebx, 2, S43, 02ad7d2bbh
II ebx, ecx, edx, eax, 9, S44, 0eb86d391h

```

```

pop edi
add dword [edi],eax
add dword [edi+04h],ebx
add dword [edi+08h],ecx

```

```

    add dword [edi+0Ch],edx
    pop esi
    pop ebx
    pop edx
    pop eax
    sub eax,64
    test edx,edx
    jne _n0
    add esp,64
    popad
    ret 0Ch

; *****
; *****

align 4, nop

tens:
    dd 10
    dd 100
    dd 1000
    dd 10000
    dd 100000
    dd 1000000
    dd 10000000
    dd 100000000
    dd 1000000000

x_numberDisplay:    ; either dotDecimal or dotHex , depending on the BASE to use to display numbers
    dd dotDecimal

v_blk:              ; the currently edited block
    dd START_BLOCK_NUMBER          ; the default edited block

v_otherBlock:       ; the previously edited block
    dd 510 ; START_BLOCK_NUMBER + 1 ; the default other block is the shadow of the default edited block

v_otherBlocks:      ; the previously edited block array
    dd START_BLOCK_NUMBER          ; the default edited block
    dd START_BLOCK_NUMBER + 1      ; the default other block is the shadow of the default edited block
    dd START_BLOCK_NUMBER + 2      ; the default other block is the shadow of the default edited block
    dd START_BLOCK_NUMBER + 3      ; the default other block is the shadow of the default edited block

v_help_counter:     ; cycles through the help screens used by "help" ( F1 key )
    dd 0

v_saved_v_blk:      ; the block number saved by "help"
    dd 0xFF

v_curs:             ; the offset in cells of the cursor within a block
    dd 0

v_cursPtr:          ; variable to count the cursor offset from the start of the block
    dd 0

v_cursLine:         ; which line we want to display the cursor on
    dd 0

v_curs_number_down: ; to limit the steps down
    dd 0

v_numberOfMagentas:
    dd 0

v_numberOfBigConstants:
    dd 0

v_numberOfRedAndMagentas:
    dd 0

```

```

v_numberOfTokens:    ; in the current block
    dd 0

v_cad:               ; the address of the cursor as an offset from the start of the currently displayed
block
    dd 0

v_pcad:              ; saved pointer to current cursor address (?)
    dd 0

v_lcad:              ; saved length of 32 bit cells to move (?)
    dd 0

v_trash:              ; pointer to "trash" buffer, saves words deleted while editing
    dd TRASH_BUFFER

v_offset:
    dd ( RELOCATED >> ( 2 + 8 ) )

v_bitsPerPixel:
    dd 16    ; default, set using VESA info

v_iconw:
    dd 0 ; iconw

v_iconh:
    dd 0 ; iconh

v_keypadY_iconh:
    dd 0    ; keypadY * iconh

v_nine_iconw:
    dd 0

v_twentytwo_iconw:   ; width of 12 history characters, 1 space and 9 keypad characters
    dd 0    ; to calculate the start of the history display, subtracted from the right edge of the
screen

v_10000_iconw:
    dd 0    ; iconw*0x10000

x_qwerty:            ; selects non-QWERTY if set to 0, else jumps to the address
    dd 0xFFFFFFFF ;

x_abort:
    dd abort_action

x_colourBlind:       ; ( state -- state )
    dd colourBlindAction

; byte variables
v_seeb:              ; if = 255, show blue words in editor
    db 0            ; 255 enable, 0 disable

v_colourBlindMode:   ; if = 255, select ANS style editor display
    db 0            ; 255 enable, 0 disable

v_not_cr:            ; true to disable the cr before a red word is displayed in the editor
    db 0

v_quitMode:          ; if non zero, the keypad is in Edit mode, else TIB mode
    db 0            ; 255 enable, 0 disable

v_hintChar:          ; the character to display in the bottom right hand corner of the keyboard
    dd 0            ; as a hint to the colour being used

v_random:            ; the current Marsaglia Pseudo Random Number Generator state
    dd 0

v_show_ASCII:        ; if true show the ASCII keyboard entry field at the cursor

```

```

    db 0

; align 4, nop    ; so we can read these variables easily from Forth
; md5_output: times 4 dd 0    ; the MD5 hash output

align 4

currentKeypadIcons:
    dd ( alphaKeypad - 4 )

shiftAction:        ; the table of Forth words to execute for the current keypad
    dd alpha0

vars:                ; colorForth system variables start here
base:
    dd 10

setCurrentBase:      ; set the base to either decimal or hexadecimal
    dd setBase_decimal

keypad_colour:
    dd colour_yellow    ; current key colour for displaying key presses

chars:
    dd 1

aword:
    dd ex1

anumber:
    dd nul

v_words:
    dd 1

v_qwerty_key:
    dd 0

v_digin:
    dd 0

lit:
    dd adup

v_washColour:
    dd colour_background

mark_MacroWordCount:
    dd MACRO_INITIAL_WORD_COUNT ; initial #macros
    ; number of Macro words, saved by mark , empty restores to this value
mark_v_ForthWordCount:
    dd FORTH_INITIAL_WORD_COUNT ; initial #words
    ; number of Forth words, saved by mark , empty restores to this value

mark_H:
    dd H0    ; 0x100000    ; top of dictionary pointer H , saved by mark , empty restores to this value

v_H:
    dd H0    ; 0x40000*4    ; variable H , dictionary pointer HERE, where new definitions go

v_last:
    dd 0

v_font:    ; a pointer to the current font table
    dd ( font16x24 )    ; default font

class:
    dd 0

v_onesec:    ; one second's worth of counter counts

```

```

        dd 0
        dd 0
v_khz:      ; the Processor clock, scaled down to kHz
        dd 0
v_mhz:      ; the Processor clock, scaled down to MHz
        dd 0

list:
        dd 0
; ( list + 4 )
        times 0x100 dd 0

v_ForthWordCount:
        dd FORTH_INITIAL_WORD_COUNT ; initial #words ; number of words in the Forth wordlist, empty resets this
value

v_MacroWordCount:
        dd MACRO_INITIAL_WORD_COUNT ; initial #macros ; number of words in the Macro wordlist, empty resets this
value

v_pad:                                     ; the standard Forth PAD, 84 bytes long
        times 84 db 0x00

tokenActions:
        ;
        dd qignore      ; 0 extension token
        dd execute_lit  ; 1
        dd num          ; 2
adefine: ; where definitions go, either in the Macro Dictionary or Forth Dictionary
        dd forthd       ; 3
        dd qcompile     ; 4
        dd cnum         ; 5
        dd cshort       ; 6
        dd compile      ; 7
        dd short_       ; 8
        dd nul          ; 9
        dd nul          ; A
        dd nul          ; B
        dd m_variable   ; C magenta variable
        dd nul          ; D
        dd nul          ; E
        dd nul          ; F

v_xy:      ; variable that holds the XY position for drawing characters, ( 0, 0 ) is top left
v_y:
        dw 0x0003
v_x:
        dw 0x0003

v_leftMargin:
        dd 0x00000003 ; left margin

v_rightMargin:
        dd 0          ; right margin

; xycr:
; dd 0

v_fov:      ; abstract display scale
        dd 0          ; 10 * ( 2 * scrnh + scrnh / 2 )

vframe:      ; pointer to display frame buffer where we create our image, down from top of 32 Mbytes RAM (
0x2000000 )
        dd 0x20000000 - ( MAX_SCREEN_WIDTH * MAX_SCREEN_HEIGHT * BYTES_PER_PIXEL )

; v_frameBuffer:      ; framebuffer address
; dd 0x00000000      ;

v_foregroundColour:
        dd 0x00000000 ; the display foreground colour, set by color

```

```

v_xc:
  dd 0x00000000      ;
v_yc:
  dd 0x00000000      ;

MacroNamesROM:
  dd 0xF0000000      ; semicolon ";"
  dd 0xC19B1000      ; dup
  dd 0xCF833620      ; qdup
;   dd 0xFF833620      ; ?dup
  dd 0xC0278800      ; drop
  dd 0x2C88C000      ; then
  dd 0xC6957600      ; begin_
; MacroNamesROM_end:

MacroJumpTableROM:      ; jump table for the macro wordlist
  dd semicolon          ; ;
  dd cdup                ; compile dup
  dd qdup                ; qdup
;   dd qdup              ; ?dup
  dd cdrop               ; compile drop
  dd then                ;
  dd begin_              ;
MacroJumpTableROM_end:

ForthNamesROM:          ; displayed using cf2ansi
  dd 0xC6664000          ; boot
  dd 0xBA8C4000          ; warm
  dd 0xC4B9A080          ; pause
  dd 0x8AC84C00          ; macro
  dd 0xB1896400          ; forth
  dd 0x90000000          ; c
  dd 0x1A635000          ; rlba      Read_Sector_LBA
  dd 0xBD31A800          ; wlba      Write_Sector_LBA
  dd 0x145C1000          ; reads     ReadSectors
  dd 0xB8B92400          ; writes    WriteSectors
  dd 0x84200000          ; sss       SaveAll_
;   dd 0x2C800000          ; th       th_ ( thunk to BIOS Int 0x13 )
  dd 0x145C0000          ; read      bios_read
  dd 0xB8B92000          ; write     bios_write
;   dd 0x18248800          ; rsect
  dd 0xF9832800          ; @dx       fetchDX_
  dd 0xF5817100          ; !dap
  dd 0x59100000          ; act(tivate)
  dd 0x8643B800          ; show
  dd 0xA1AE0000          ; load
  dd 0x6A1AE000          ; nload
  dd 0xF7435C00          ; +load
  dd 0x2C839800          ; thru
  dd 0xF6590730          ; +thru
  dd 0x963A7400          ; cblk      return the block number currently being compiled, calculated from edi
  dd 0x1C74E800          ; rblk      return the block number offset of the RELOCATED address
  dd 0x5C74E800          ; ablk      4 / cellAddressToBlock
  dd 0x41582000          ; erase
  dd 0xC8828000          ; here
  dd 0xFF472000          ; ?lit
  dd 0xD7F80000          ; 3,
  dd 0xD5F80000          ; 2,
  dd 0xD3F80000          ; 1,
  dd 0x97E00000          ; c,
  dd 0xFC000000          ; ,
  dd 0xA2420000          ; less
  dd 0xE59A3880          ; jump
  dd 0xCF99C800          ; quit_      was accept = dd 0x59493110
  dd 0xC4B80000          ; pad_
  dd 0xC3019640          ; vsrch_
  dd 0x80CB2000          ; srch_
  dd 0xE893C580          ; keypd_
  dd 0xBBE24000          ; wipe
  dd 0xBBE24800          ; wipes      was erase

```

```

dd 0x91E29800 ; copy
dd 0x8A8F4000 ; mark
dd 0x48E22980 ; empty
dd 0x48B90000 ; emit
dd 0x29E24000 ; type type_
dd 0xC0F57200 ; digit
dd 0xD4917200 ; 2emit
dd 0xEA000000 ; .
dd 0xC9D75000 ; h.2 dotHex2_
dd 0xC9D76000 ; h.4 dotHex4_
dd 0xC9D40000 ; h. dotHex8_
dd 0xC9D58000 ; h.n
dd 0x90800000 ; cr
dd 0x86259200 ; space
dd 0xC0776000 ; down
dd 0x4C0E4000 ; edit
dd 0x40000000 ; e
dd 0xA4400000 ; lm
dd 0x18800000 ; rm
dd 0xA8AE2C80 ; graph
dd 0x24CA4000 ; text
dd 0xE893C4A0 ; keypa(d) displayTheKeypad was 0xE893C660 keybo(ard)
dd 0xC098F300 ; debu(g)
dd 0x52000000 ; at
dd 0xF6A40000 ; +at
dd 0xCB300000 ; xy
dd 0xC4B54000 ; page
dd 0x84851180 ; screen
dd 0xB1E10000 ; fov
; dd 0xB3D8C000 ; fifo
dd 0xC6794000 ; box
dd 0xA3B20000 ; line
dd 0x91D0C400 ; color
dd 0x3912B100 ; octant
dd 0x86200000 ; sp
dd 0xA2C08000 ; last
dd 0xCCD89640 ; unpac(k)
dd 0xC4B2E800 ; pack
dd 0xC74E8000 ; blk
dd 0x8485AE00 ; scrnw screen width in pixels
dd 0x8485B200 ; scrnh screen height in pixels
dd 0xC78B1000 ; bpp bits per pixel
dd 0xB1B10000 ; font address of font pointer, containing by default font16x24
dd 0x791B5C00 ; iconw icon width in pixels
dd 0x791B6400 ; iconh icon height in pixels
dd 0x91E66240 ; counte(r) counter
dd 0x8C000000 ; ms ms_
dd 0x36482480 ; onesec onesec_
dd 0xE993B000 ; khz khz_
dd 0x1297C000 ; rtc@ rtc_fetch_
dd 0x1297A000 ; rtc! rtc_store_
dd 0x92D25D00 ; calck calck_
dd 0xC2820000 ; ver
dd 0x96618000 ; curs
dd 0xC7439740 ; block
dd 0xC36158A0 ; vframe video frame address, where we create the image to be displayed
dd 0xC2A30000 ; vars
; new words
dd 0x82263000 ; seeb ( see blue words, toggle )
dd 0x812CBA40 ; stacks_
dd 0xC0650B00 ; dotsf type a ShannonFano token
dd 0xA22E1400 ; leave
; dd 0x12312310 ; txtq
dd 0x1AE30000 ; rgb
dd 0xC7340000 ; bye
dd 0xB98E0000 ; word
dd 0x4E840000 ; ekt
dd 0x5C662400 ; abort
dd 0x27974C80 ; tickh HERE variable address
dd 0xC79AD640 ; buffe(r) buffer_

```



```

dd 0x3B5A0840 ; offset
dd 0x27900000 ; tic tic_
dd 0xC2905000 ; vesa
dd 0xC2905880 ; vesam
dd 0x21586400 ; trash trash_
; dd 0xC90C3840 ; hsvv_
dd 0xC3731C00 ; vword
; dd 0xC2295800 ; vregs
dd 0x7C292000 ; ivec
dd 0x14863000 ; resb restore_BIOS_idt_and_pic
dd 0xC4F20000 ; pic
dd 0xC0B88000 ; dap
dd 0x82488000 ; sect
dd 0xB98E0800 ; words
dd 0xE8930000 ; key
dd 0xCFD12600 ; qkey
dd 0xC0F57600 ; digin
dd 0xCF741200 ; qwert
dd 0x1FE00000 ; r?
dd 0x6CD40000 ; nul
dd 0x92E00000 ; cad
dd 0xC525C000 ; pcad
dd 0xC0F0C540 ; displ(ay)
dd 0x59148000 ; actc
dd 0xF7478100 ; +list
dd 0x72797400 ; itick
dd 0xA3C00000 ; lis1
dd 0xF6800000 ; +e
dd 0x820E1D20 ; serv1 serv1_
dd 0x780E1D20 ; isrv1_ initerv1_
dd 0x820E1D40 ; serv2 serv2_
dd 0x780E1D40 ; isrv2_ initerv2_
dd 0x4C0E4A00 ; edita editAddress
dd 0x963A3B60 ; cblind

dd 0x97C00000 ; c@ cFetch_
dd 0xBFC00000 ; w@ wFetch_
dd 0xF8000000 ; @ fetch_ was replaced by optimising version in block 70
dd 0xD5F00000 ; 2@ two_fetch_ was replaced by optimising version in block 70

dd 0x97A00000 ; c! cStore_
dd 0xBF000000 ; w! wStore_
dd 0xF4000000 ; ! store_ was replaced by optimising version in block 70
dd 0xF7E80000 ; +! plus_store_
dd 0xD5E80000 ; 2! two_store_ was replaced by optimising version in block 70

dd 0xC0C95000 ; dneg d_negate_
dd 0xC1EC0000 ; d+ d_plus_
dd 0xC1CC0000 ; d- d_minus_
dd 0xD5833620 ; 2dup two_dup_

dd 0xD5804F10 ; 2drop two_drop_ bug fix from Marco Nicola
dd 0xD50BAE20 ; 2swap two_swap_
dd 0xD4785040 ; 2over two_over_
dd 0x13200000 ; rot rot_
dd 0xE6264000 ; -rot minus_rot_
dd 0x2CD2E800 ; tuck tuck_
dd 0xC4F2E800 ; pick pick_

dd 0x92528000 ; cell cell_
dd 0x92529CC0 ; cell- cell_minus_
dd 0x92529EC0 ; cell+ cell_plus_
dd 0x92529000 ; cells cells_

dd 0xA6200000 ; lp lp_

dd 0xA3E02000 ; lidt lidt_
dd 0x83E02000 ; sidt sidt_

dd 0xD5DC0000 ; 2/ two_slash_

```

```

dd 0xCDABB800 ; u2/      u_two_slash_
dd 0x18647B10 ; rshift   rshift_
dd 0xCDABB800 ; lshif    lshift_
dd 0xFBDC0000 ; */       star_slash_
dd 0xCDF7B800 ; u*/      u_star_slash_
dd 0xEf13C000 ; /mod     slash_mod_
dd 0xFBDE2780 ; */mod     star_slash_mod_
dd 0x944F0A00 ; cmove_    cmove
dd 0xD5F40000 ; 2*       two_star_
dd 0xD5F7E800 ; 2**      two_star_star_
; dd 0xD5DC0000 ; u/      u/_
dd 0x962CCF80 ; cpuid    GetCPUID_
dd 0x1C050900 ; rdtsc    rdtsc
dd 0x156C0000 ; rand     rand_
dd 0x156C1DC0 ; rand/    randInit_
dd 0x156C19C0 ; randq    randq_
dd 0x90CB5EA0 ; crc32    crc32_
dd 0x8E0DA000 ; md5      md5_

; dd 0xB18C5480 ; format
; dd 0xC5270000 ; pci
; dd 0x68248000 ; nsec      was devic(e)
dd 0x85DCA590 ; switch
dd 0xB0A27640 ; freeze
dd 0x23C40000 ; top
; dd 0xB1896480 ; forths
; dd 0x8AC84E00 ; macros
dd 0           ; terminating null at the end of the list

ForthJumpTableROM: ; jumtable:
dd boot        ;
dd warm        ;
dd pause_      ; pause
dd macro       ;
dd forth       ;
dd c_          ; c
dd Read_Sector_LBA - $$ + BOOTOFFSET ; jmp Read_Sector_LBA
dd Write_Sector_LBA - $$ + BOOTOFFSET ; jmp Write_Sector_LBA
dd ReadSectors - $$ + BOOTOFFSET ; jmp ReadSectors reads
dd WriteSectors - $$ + BOOTOFFSET ; jmp WriteSectors writes
dd SaveAll_ - $$ + BOOTOFFSET ; jmp SaveAll_
; dd th_ - $$ + BOOTOFFSET ; jmp th_ ( thunk to BIOS Int 0x13 )
dd bios_read - $$ + BOOTOFFSET ; jmp bios_read 'read'
dd bios_write - $$ + BOOTOFFSET ; jmp bios_write 'write'
; dd XXXrsect_ - $$ + BOOTOFFSET ; jmp rsect_ 'rsect'
dd fetchDX_ ; @dx
dd setupDAP_ ; !dap
dd activate ; act
dd show ;
dd _load_ ;
dd nload ; nload
dd plusLoad ; +load
dd thru_ ; thru
dd plusThru_ ; +thru
dd cblk_ ; return the block number currently being compiled, calculated from edi
dd rblk_ ; return the block number offset of the RELOCATED address
dd ablk_ ; convert byte address to block number
dd erase_ ;
dd here ;
dd qlit ; ?lit
dd comma3_ ; 3,
dd comma2_ ; 2,
dd comma1_ ; 1,
dd comma1_ ; c,
dd comma_ ; ,
dd less ; less
dd jump ; jump
dd quit_ ; quit
dd pad_ ; pad
dd vsrch_ ; vsrch

```

```

dd srch_          ; srch
dd keypd_         ; keypd ( alias of pad )
dd wipe          ;
dd wipes         ;
dd copy_         ; copy
dd mark          ;
dd empty_        ; empty
dd emit_         ; emit
dd type_         ; type
dd digit         ;
dd two_emit      ; 2emit
dd dotDecimal    ; .
dd dotHex2_      ; h.2
dd dotHex4_      ; h.4
dd dotHex8_      ; h.
dd h_dot_n       ; h.n
dd cr_           ; cr
dd space_        ; space
dd down          ;
dd edit_         ;
dd e_            ; e
dd lm           ;
dd rm           ;
dd graphAction   ; graph
dd setupText_    ; text
dd displayTheKeypad ;
dd debug         ;
dd _at          ; at
dd plus_at      ; +at
dd xy_          ;
dd page_        ; page
dd screen_      ; screen
dd fov_         ;
; dd fifo        ;
dd box_         ; box
dd line_        ; line
dd color        ;
dd octant       ;
dd tokenActions_ ; tokenActions table
dd last         ;
dd unpack       ;
dd pack_        ;
dd blk_         ;
dd scrnw_       ; scrnw screen width in pixels
dd scrnh_       ; scrnh screen height in pixels
dd bpp_         ; bpp bits per pixel
dd font_        ; font address of font pointer, containing by default font16x24
dd iconw_       ; iconw icon width in pixels
dd iconh_       ; iconh icon height in pixels
dd counter_     ; counter
dd ms_          ; ms
dd onesec_      ; onesec
dd khz_         ; khz
dd rtc_fetch_   ; rtc@
dd rtc_store_   ; rtc!
dd calck_       ; calclk calibrate the clock for ms
dd version_     ; ver
dd curs         ; curs
dd block_       ; block
dd vframe_      ; vframe
dd vars_        ; vars
; new words
dd seeb         ; seeb
dd stacks_      ;
dd dotsf_       ; dotsf
dd leave_       ; leave
; dd txtq_      ;
dd rgb          ; rgb
dd bye_         ; bye
dd _word        ;

```

```

dd ekt          ;
dd abort        ;
dd tickh        ;
dd buffer_      ; buffe(r)
dd offset_      ;
dd tic_         ; tic
dd vesa         ;
dd vesamode_    ;
dd trash_       ; trash
; dd hsvv_      ; hsvv
dd vword_       ; ('%s')", DB_NAME,
; dd vregs_     ; vregs
dd ivec_        ; ivec
dd restore_BIOS_idt_and_pic ; resb
dd pic_         ; pic Programmable Interrupt Controller settings, as set by the BIOS
dd dap_         ; dap
dd sect_        ; sect
dd words_       ; words
dd get_key_     ; key
dd get_qwerty_key_ ; qkey
dd digin        ;
dd qwert        ;
dd rquery       ; r?
dd nul         ;
dd cad          ;
dd pcad         ;
dd displ        ;
dd actc         ;
dd pluslist     ; +list
dd itick        ;
dd refresh      ; lis
dd plus_e       ; +e
dd serv1_       ; serv1
dd initerv1_    ; isrv1_
dd serv2_       ; serv2
dd initerv2_    ; isrv1_
dd editAddress  ; edita
dd cBlindAddr_  ; cblind

dd cFetch_      ; c@
dd wFetch_      ; w@
dd fetch_       ; @      was replaced by optimising version in block 70
dd two_fetch_   ; 2@     was replaced by optimising version in block 70
dd cStore_      ; c!
dd wStore_      ; w!
dd store_       ; !      was replaced by optimising version in block 70
dd plus_store_  ; +!
dd two_store_   ; 2!     was replaced by optimising version in block 70

dd d_negate_    ; dneg
dd d_plus_      ; d+
dd d_minus_     ; d-
dd two_dup_     ; 2dup
dd two_drop_    ; 2drop
dd two_swap_    ; 2swap
dd two_over_    ; 2over
dd rot_         ; rot
dd minus_rot_   ; -rot
dd tuck_        ; tuck
dd pick_        ; pick

dd cell_        ; cell
dd cell_minus_  ; cell-
dd cell_plus_   ; cell+
dd cells_       ; cells
dd lp_          ; lp
dd lidt_        ; lidt
dd sidt_        ; sidt
dd two_slash_   ; 2/
dd u_two_slash_ ; u2/

```

```

dd rshift_      ; rshift
dd lshift_      ; lshif      lshift
dd star_slash_  ; */
dd u_star_slash_ ; u*/
dd slash_mod_   ; /mod
dd star_slash_mod_ ; */mod
dd cmove_       ; cmove
dd two_star_    ; 2*
dd two_star_star_ ; 2**      _
;   dd u/_       ; u/

dd GetCPUID_    ; cpuid
dd rdtsc_       ; rdtsc
dd rand_        ; rand
dd randInit_    ; rand/
dd randq_       ; randq
dd crc32_       ; crc32
dd md5_         ; md5

;   dd format      ;
;   dd pci         ;
;   dd device      ;
;   dd switch      ;
;   dd freeze      ;
;   dd top_        ;
;   dd forths_     ;
;   dd macros_     ;

```

ForthJumpTableROM_end:

```

; times 200 NOP      ; enable this line to see how much space is left. If NASM reports :
; "cf2022.nasm:6282: error: TIMES value -28 is negative" with "times 200" you have (200 - 28) bytes left

; fill with no-ops to 55AA at end of boot sector, less $40 for the info string
times ( ( START_BLOCK_NUMBER - SIZE_OF_FONT_IN_BLOCKS ) * 0x400 ) - ($ - $$) NOP

; the above produces a 26K boot image, we then add the 6K font and colorForth source blocks:
font16x24:
; incbin "cf2022_font.img"
; incbin "cf2022Ref.img", ( OFFSET_OF_FONT +(SIZE_OF_FONT_IN_BLOCKS *1024) ), ( 512 * 1024 ) ; append the
font and colorForth source blocks from the reference image, skip the kernel code
; colorForth:                ; the colorForth source blocks
incbin "cf2022Ref.img", OFFSET_OF_FONT, ( ( 512 - START_BLOCK_NUMBER + SIZE_OF_FONT_IN_BLOCKS ) * 1024 );
append the font and colorForth source blocks from the reference image, skip the kernel code
times 32768 db 'U'
; incbin "cf2022Ref.img", OFFSET_OF_FONT - (( 64 - 38 ) * 1024 ), ( ( 512 - START_BLOCK_NUMBER +
SIZE_OF_FONT_IN_BLOCKS ) * 1024 ); append the font and colorForth source blocks from the reference image,
skip the kernel code

; end of file

```

Appendix C colorForth Source Code

\.cf2022\cf2022Ref.img converted by colorForthScan V1.0 2022 Apr 08
 \ File MD5 = 9FE7E198347E027576A65D1289F561A0 sitar-flatfish

\ MagentaV is the colorForth Magenta Variable
 : MagentaV (initial --) create , ; \ Runtime: (-- a)

\ Block 64
 (colorforth cf2022 2022 Sep 24)
 (processor clock) #4 MagentaV mhz
 (dump) #587776 MagentaV x #0 MagentaV y (ld) #80 MagentaV lblk
 #2 #12 +thru
 : dump #78 load ;
 : icons #80 ld ; : serve #506 ld ;
 : north #92 ld ; : rtc #96 ld ;
 : lan #98 ld ; : colors #102 ld ;
 : wood #106 ld ; : mand #108 ld ;
 : sound #114 ld ; : gr #118 ld ;
 : eth #176 ld ; : life #272 ld ;
 : ed #252 ld ; : slime #246 ld ;
 : int #288 ld ; : xx #278 load ;
 : info ver dump ; : staks #504 ld ;

(hardware) #0 MagentaV rng
 : chm (--) #0 mhz ! \$1740 x ! #0 y ! #64 lblk ! \$00010000
 : ch (n--) #64 block swap md5 dump ;
 : hlp randq rng ! logo pause calkhz
 : onesec @ #1000 / mhz ! e ;
 mark empty hlp

(Press the * key to see the comment block)

(Press F1)

\ Block 65
 \ (Based on colorforth 2001 Jul 31 by Chuck Moore)
 \ (released into the Public Domain.)
 \ (This block is loaded at power up. Press F1 for help)
 \ : dump (instant compile version of DUMP)
 \ : icons (edit the character font icons)
 \ : north (North Bridge PCI chip display)
 \ : rtc (Real Time Clock display)
 \ : colors (3-axis rgb colour display)
 \ : wood (imitation pine blockboard)
 \ : mand (display the Mandeldrot set)
 \ : sound (control the PC speaker)
 \ : gr (graphics - type ok to run the demo)
 \ : life (Conways game of life)
 \ : ed (the editor partly converted to colorforth)
 \ : slime (watch out for the slugs!)
 \ : int (1000 Hz timer interrupt)
 \ : xx (colorforth explorer)
 \ : ch (show MD5 of n bytes starting at block 64)
 \ : chm (show MD5 of system blocks)
 \ : help (press the space bar to leave the editor, then type the keys indicated in the keypad in the bottom right of the
 \ screen, then the space bar to execute the word. Type) e (or) #64 edit (to run the editor.)
 \ info (to view the boot system version)
 \ seeb (to toggle display of blue words)
 \ hlp (shows help and clock speed)

\ Block 66
 macro
 : ?f \$C021 2, ;
 : 0if \$75 2, here ;
 : +if \$78 2, here ;
 : 1+ (n-n) \$40 1, ;
 : 1- (n-n) \$48 1, ;
 : 2/ (n-n) \$F8D1 2, ;
 : time (-u) qdup \$310F 2, ;
 : shl (uc-u) ?lit \$E0C1 2, 1, ;

```

: shr ( uc-u ) ?lit $E8C1 2, 1, ;
: r@ qdup $8B 1, $C7 1, ;
: sti $FB 1, ; ( enable interrupts )
: cli $FA 1, ; ( disable interrupts ) forth
: cli cli ;
: sti sti ;
: nul ;
: time time ;

\ Block 67
\ ( Pentium macros: )
\ : ?f ( set flags to reflect tos )
\ : 0if ( if zero ... then jnz aids in clarity )
\ : +if ( js, this complements the set )
\ : 1- ( subtract 1 )
\ : 2/ ( divide by 2 )
\ : qdup ( is the new name for ?dup )
\ : time ( return Pentium instruction counter )
\ : lshift ( shift u left c places )
\ : rshift ( shift u right c places )
\ : r@ ( copies the top of the return stack to TOS )
\ : sti ( enable device interrupts )
\ : cli ( disable them )
\ : a,

\ Block 68
( more macros ) macro
: swap $168B 2, $C28B0689 , ;
: 0 qdup $C031 2, ; : if $74 2, here ;
: -if $79 2, here ; : a qdup $C28B 2, ;
: a! ?lit if $BA 1, , ; then $D08B 2, drop ;
: 1@ $8A 2, ; : 1! a! $0288 2, drop ;
: p@ ( a-n ) qdup a! $EC 1, ;
: p! ( na- ) a! $EE 1, drop ;
: 2* $E0D1 2, ;
: a, , ;
: @ ?lit if qdup $058B 2, , ; then $8B 2, 0 , ;
: ! ?lit if ?lit if $05C7 2, swap , , ; then $0589 2, , drop ; then a! $0289 2, 0 , drop ;
: nip $0004768D 3, ;
: + ?lit if $05 1, , ; then $0603 2, nip ;
: xor $0633
: binary ?lit if swap #2 + 1, , ; then 2, nip ;
: and $0623 binary ;
: or $060B binary ;
: u+ ?lit if $0681 2, , ; then $00044601 3, drop ;
: ? ?lit $A9 1, , ;

\ Block 69
\ ( Pentium macros: 1, 2, 3, , compile 1-4 bytes )
\ : drop ( lodsd, flags unchanged, why sp is in ESI )
\ : over ( sp 4 + @ )
\ : swap ( sp xchg )
\ : 0 ( 0 0 xor, macro 0 identical to number 0 )
\ : a ( 2 0 mov, never used? )
\ : a! ( 0 2 mov, unoptimized )
\ : 1@ ( fetch byte from byte address )
\ : 1! ( store byte to byte address )
\ : p@ p-n ( fetch byte from port )
\ : p! np ( store byte to port )
\ : @ ( EAX 4 *, unoptimized )
\ : ! ( EDX 4 * )
\ : nop ( used to thwart look-back optimization )
\ : - ( ones-complement )
\ : 2*
\ : 2/
\ : if ( jz, flags set, max 127 bytes, leave address )
\ : -if ( jns, same )
\ : then ( fix address - in kernel )
\ : push ( EAX push )
\ : pop ( EAX pop )
\ : u+ ( add to 2nd number, literal or value )

```

```

\ : ? ( test bits, set flags, literal only! )

\ Block 70
( even more macros )
: over qdup $0004468B 3, ;
: push $50 1, drop ;
: pop qdup $58 1, ;
: invert ( n-n ) $D0F7 2, ;
: for push begin ;
: *next swap
: next $75240CFF
: 0next , here invert + 1, $0004C483 3, ;
: -next $79240CFF 0next ;
: i qdup $0024048B 3, ;
: *end swap
: end $EB 1, here invert + 1, ;
: +! ?lit if ?lit if $0581 2, swap , , ; then $0501 2, , drop ; then a! $0201 2, drop ;
: nop $90 1, ;
: align here invert #3 and drop if nop align ; then ;
: or! a! $00950409 3, 0, drop ;
: * $0006AF0F 3, nip ;
: */ $C88B 2, drop $F9F72EF7 , nip ;
: /mod swap $99 1, $16893EF7 , ;
: //mod nip ;
: mod /mod drop ;

\ Block 71
\
\ : - n-n ( ones complement negate , xor )
\ : for n ( push count onto return stack, falls into ) begin
\ : begin -a ( current code address - byte )
\ : *next aa-aa ( swap ) for ( and ) if ( addresses )
\ : next a ( decrement count, jnz to ) for, ( pop return stack when done )
\ : -next a ( same, jns - loop includes 0 )
\ : i -n ( copy loop index to data stack )
\ : end a ( jmp to ) begin
\ : +! na ( add to memory, 2 literals optimized )
\ : align ( next call to end on word boundary )
\ : or! na ( inclusive-or to memory, unoptimized )
\ : * mm-p ( 32-bit product )
\ : */ mnd-q ( 64-bit product, then quotient )
\ : /mod nd-rq ( remainder and quotient )
\ : / nd-q ( quotient )
\ : mod nd-r ( remainder )
\ : time -n ( Pentium cycle counter, calibrate to get actual clock rate )

\ Block 72
( Compiled macros ) forth
: r@ ( -n ) r@ ;
: @ ( a-n ) @ ;
: ! ( an- ) ! ;
: + ( nn-n ) + ;
: 1+ ( u--u ) 1+ ;
: 1- ( u--u ) 1- ;
: invert ( n-n ) invert ;
: */ ( nnn-n ) */ ;
: * ( nn-n ) * ;
: / ( nn-n ) / ;
: 2* ( n-n ) 2* ;
: 2/ ( n-n ) 2/ ;
: dup ( n-nn ) dup ;
: swap ( nn-nn ) swap ;
: over over ;
( Arithmetic )
: negate ( n-n ) invert #1 + ;
: - ( nn-n ) negate + ;
: min ( nn-n ) less if drop ; then swap drop ;
: abs ( n-u ) dup negate
: max ( nn-n ) less if swap then drop ;
: v+ ( vv-v ) push u+ pop + ;
: save sss ;

```



```

: sa sss sss e ;

\ Block 73
\ ( These macros may be ) yellow, ( others may not )
\ : block n-a ( block number to word address )
\ : r@ ( copies the top of the return stack to stack )
\ : @ etc ( Arithmetic )
\ : negate n-n ( when you just cant use ) -
\ : min nn-n ( minimum )
\ : abs n-u ( absolute value )
\ : max nn-n ( maximum )
\ : v+ vv-v ( add 2-vectors )
\ : save ( write colorforth to a bootable USB drive )
\ : sa ( save, then show edit screen )

\ Block 74
( Relative load blocks )
: ll ( -- ) blk @ load ;
: sect ( --asn ) blk @ block blk @ 2* #2 ;
: ss ( -- ) sect writes drop drop ;
: uu ( -- ) sect reads drop drop ;

: ld ( n- ) dup lblk ! load ;
: vv ( -- ) lblk @ edit ;
: help ( -- ) lblk @ #1 + edit ;
( Real Time Clock )
: rtc@ ( t-c ) $70 p! $71 p@ ;
: rtc! ( ct- ) $70 p! $71 p! ;
: hi ( -- ) #10 rtc@ $80 and drop 0if hi ; then ;
: lo ( -- ) #10 rtc@ $80 and drop if lo ; then ;

: calkhz ( -- ) hi lo counter hi lo counter swap -
  dup onesec ! #1 rshift #250 + #500 / dup khz ! ;
: ms ( n- ) khz @ * counter + begin pause dup counter
  invert + drop -if drop ; then end drop ;
: secs ( n- ) for pause lo hi next ; macro
: swapb ( w-w ) $E086 2, ; forth
: split ( w--cc ) dup swapb $FF and swap $FF and ;

\ Block 75
\
\ : nload ( loads the next source block : b+2 )
\ : +load ( loads the source block : b+n )
\ : blk ( where the current blk happens to be kept )
\ : ll ( load the current edit blk )
\ : ss ( save the sector containing the current edit block to the floppy disc )
\ : lblk ( holds the last block loaded by )
\ : ld
\ : vv ( edits the last block loaded by ld )
\ : rtc@ reg-n ( fetch reg from rtc )
\ : rtc! n reg- ( store in rtc register )
\ : hi ( wait till Update In Progress bit is high )
\ : lo ( wait till UIP bit is low )
\ : calkhz ( calibrate the processor clock using the RTC )
\ : ms ( wait for n milliseconds )
\ : secs ( wait for n seconds )
\ : swapb ( swap the two low bytes )
\ : split ( split the low two bytes )
\ : vframe ( byte address of the video frame buffer )

\ Block 76
( Colors etc )
: white $00FFFFFF rgb color ; ; red $00FF0000 rgb color ;
: green $FF00 rgb color ; ; blue $FF rgb color ;
: silver $00BFBFBF rgb color ; ; yellow $FFE0 color ;
: orange $00E04000 rgb color ; ; black $00 rgb color ;
: 5* #5 for 2emit next ;
: cf #25 dup at red $72 $6F $6C $6F $63 5* green $68 $74 $72 $6F $46 5* ;
: logo show black screen #800 #710 blue box #600 #50 at #1024 #620 red box #200 #100 at #700 #500 green box text cf keypa
d ;
: noshow show keypad ;

```

```

: lshift ( uc-u ) $1F and ?f 0if drop ; then for #1 shl next ;
: rshift ( uc-u ) $1F and ?f 0if drop ; then for #1 shr next ;
: rand32 ( -n ) time dup #16 lshift xor ;
: string pop ;
: 1@ ( a-c ) 1@ $0F and ;
: 1! ( ac- ) 1! ;

```

```

\ Block 77
\

```

```

\ : colors ( specified as rgb: 888 )
\ : screen ( fills screen with current color )
\ : at xy ( set current screen position )
\ : box xy ( lower-right of colored rectangle )
\ : 5* ( displays 5 large characters )
\ : cf ( displays ) colorforth
\ : logo ( displays colorforth logo )
\ : empty ( also displays the logo )
\ : lshift ( shift u left c places )
\ : rshift ( shift u right c places )
\ : show ( background task executes following code repeatedly )
\ : keyboard ( displays keypad and stack )
\ : string ( returns the address of the string following )
\ : rand32 ( returns a 3 bit random number )

```

```

\ Block 78

```

```

( Dump names )
: .cell ( a-a ) orange dup @ #4 for dup $FF and emit $0100 / next drop white ;
: one dup dup @ dup push h. space dup h. pop space swap .cell drop space space space space dup dotsf drop white cr ;
: lines for one #4 + next drop ;
: dump ( a- ) $0FFFFFFC and x !
: r show black screen x @ #16 text lines cr x @ #16 for .cell #4 + next drop keypad ;
: it @ + @ dup h. space ;
: lines for white i x it i y it xor drop if red then i . cr -next ;
: cmp show blue screen text #19 lines red x @ h. space y @ h. keypad ;
: u $40
: +xy dup x +! y +! ;
: d $FFFFFFFC0 +xy ;
: ati $F4100000 ( ff7fc000 ) xor
: byte #4 / dump ;
: fix for #0 over ! #1 + next ; dump

```

```

\ Block 79

```

```

\ ( Does not say empty, compiles on top of application )
\ : x -a ( current address )
\ : one a-a ( line of display )
\ : lines an
\ : dump a ( background task continually displays memory : decodes the value as a name and ASCII )
\ : u ( increment address )
\ : d ( decrement )
\ : ati ( address of AGP graphic registers )
\ : byte a ( byte address dump )
\ : fix an-a ( test word )
\ : ver ( show the kernel version information )
\ : cmp ( shows data at both ) x ( and ) y ( addresses )

```

```

\ Block 80

```

```

( App: Icons font editor ) empty
( icon number ) #62 MagentaV ic ( cursor ) #0 MagentaV cu
macro : @w $8B66 3, ; ; !w al $00028966 3, drop ;
: *byte $C486 2, ; forth

: sq xy @ $00010000 /mod #16 + swap #16 + box #17 #0 +at ;
: loc ic @ $FF and
: tofont ( n--a ) #16 #24 #8 * / * font @ + ;
: 0/1 $8000 ? if green sq ; then blue sq ;
: row dup @w *byte #16 for 0/1 2* next drop #-17 #16 * #17 +at ; : cpl #32 ;
: showall ( -- ) #2 lm iconw cpl * rm ic @ cpl /mod iconh * #448 #2 - + swap iconw * swap over over at red #16 #4 + u+ #24
+ #4 + box white
#0 #2 #448 at #256 for dup emit #1 + next drop ;
: ikon loc #24 for row #2 + next drop ;
: adj #17 * swap ;

```

```
: cursor cu @ #16 /mod adj adj over over at red #52 u+ #52 + box ;
: ok show page cursor #18 dup at ikon text blue #400 #400 at ef #416 #424 box #400 #400 at white ef ic @ dup emit space
dup green . $30 emit $78 emit #2 h.n showall keypad ;
```

```
: fcopy tofont swap tofont swap #16 #24 #8 */ cmove ;
nload ok h
```

```
\ Block 81
\ ( Draw big-bits icon )
\ : @w a-n ( fetch 16-bit word from byte address )
\ : !w na ( store same )
\ : *byte n-n ( swap bytes )
\ : ic -a ( current icon )
\ : cu -a ( cursor )
\ : sq ( draw small square )
\ : xy -a ( current screen position, set by ) at
\ : loc -a ( location of current icons bit-map )
\ : 0/1 n-n ( color square depending on bit 15 )
\ : row a-a ( draw row of icon )
\ : +at nn ( relative change to screen position )
\ : ikon ( draw big-bits icon )
\ : adj nn-nn ( magnify cursor position )
\ : cursor ( draw red box for cursor )
\ : ok ( background task to continually draw icon, icon number at bottom )
```

```
\ Block 82
( Edit icon )
```

```
: icmv ( n-- ) ic @ + $FF and ic ! ;
: +ic #1 icmv ;      : -ic #1 icmv ;
: ++ic cpl icmv ;    : --ic cpl negate icmv ;
: bit cu @ 2/ 2/ 2/ 2* loc + $00010000 cu @ $0F and #1 + for 2/ next *byte ;
: toggle bit over @w xor swap !w ;
```

```
: td toggle      : d #16
: wrap cu @ + #16 #24 * dup u+ /mod drop cu ! ;
: tu toggle      : u #16 wrap ;
: tr toggle      : r #1 wrap ;
: tl toggle      : l #1 wrap ;
: nul ;
: h keypd
nul nul quit nul      tl tu td tr
l u d r      -ic --ic ++ic +ic
nul nul nul nul      nul nul nul toggle
      nul nul nul nul
$2500 , $13121110 dup , , $2B16152D , #0 , $80000000 , #0 ,
```

```
\ Block 83
\ ( Edit icon )
\ : t ( toggles the current pixel )
\ : ludr ( left up down right )
\ : . ( top row toggles and moves )
\ : --+ ( select icon to edit )
```

```
\ Block 84
( Print PNG to disk ) #1024 MagentaV w #768 MagentaV h #1 MagentaV d
#6 +load #4 +load #2 +load
: -crc ( a ) here over negate + crc . ;
: crc -crc ;
: wd ( -a ) here #3 and drop if #0 1, wd ; then here #2 2/s ;
: bys ( n-a ) . here swap , ;
: plte $45544C50 #48 bys $00 3, $00FF0000 3, $FF00 3, $00FFFF00 3, $FF 3, $00FF00FF 3, $FFFF 3, $00FFFFFF 3, $00 3,
$00C00000
3, $C000 3, $00C0C000 3, $C0 3, $00C000C0 3, $C0C0 3, $00C0C0C0 3, crc ;
: png ( awh ) d @ / h ! d @ / w ! wd swap $474E5089 , $0A1A0A0D , ( ihdr ) $52444849 #13 bys w @ . h @ . $0304 , $00 1, crc
plte ( idat ) $54414449 #0 bys swap deflate crc ( iend ) $444E4549 #0 bys crc wd over negate + ;
: at #1024 * + 2* vframe + ;
: full #4 d ! #0 dup at #1024 #768 png ;
: pad #1 d ! #46 #9 + #22 * nop #25 #4 + #30 * at #9 #22 * nop #4 #30 * png ;
: go #1 d ! #1024 w ! #768 h ! #0 #0 at #1024 #768 png raw ; go e
```

```

\ Block 85
\ ( Print PNG to disk )
\ : frame ( the video frame buffer )
\ : -crc ( a )
\ : crc
\ : wd ( -a )
\ : bys ( n-a )
\ : plte
\ : png ( awh )
\ : at
\ : full
\ : pad
\ : go ( copy the screen image as a PNG file to the floppy disk block 270 and up. )

\ Block 86
( lz77 ) macro
: @w $8B66 3, ;
: *byte $C486 2, ;
: !b a! $0289 2, drop ; forth
: *bys dup #16 2/s *byte swap $FFFF and *byte $00010000 * + ;
: . *bys , ;
: +or over invert and or ;
: 0/1 $10 ? if $1E and $1E or drop if #7 ; then $0F ; then #0 and ;
: 4b dup 0/1 #9 and over #6 2/s 0/1 $0A and +or swap #11 2/s 0/1 $0C and +or $08 or ;
: pix dup @w d @ 2* u+ 4b ;
: row 1, dup w @ 2/ dup #1 + dup 2, invert 2, #0 dup 1, +adl for pix #16 * push pix pop or dup 1, +adl next drop +mod d @
#1024 #2 * * + ;
: deflate $0178 2, #1 #0 ad!! h @ #-1 + for #0 row next #1 row drop ad2 @ *byte 2, ad1 @ *byte 2, here over #4 + negate +
*bys over #-4 + !b ;

\ Block 88
( Crc ) macro
: 2/s ?lit $E8C1 2, 1, ;
: 1@ $8A 2, ; forth #36054 MagentaV ad1 #54347 MagentaV ad2
: array ( -a ) pop #2 2/s ;
: bit ( n-n ) #1 ? if #1 2/s $EDB88320 or ; then #1 2/s ;
: fill ( nn ) for dup #8 for bit next , #1 + next drop ;
: table ( -a ) align array #0 #256 fill
: crc ( an-n ) #1 swap for over 1@ over or $FF and table + @ swap #8 2/s or #1 u+ next invert nip ;
: +adl ( n ) $FF and ad1 @ + dup ad2 @ +
: ad!! ad2 ! ad1 ! ;
: +mod ad1 @ #65521 mod ad2 @ #65521 mod ad!! ;

\ Block 90
( DOS file )
: blks #256 * ;
: w/c #18 blks ;
: buffer block ;
: size ( -a ) buffer #0 #1 reads buffer $098F + ;
: set ( n ) ! buffer s #1 writes ;
: cys ( n-n ) #1 swap w/c #-1 + + w/c / ;
: put ( an ) dup 2* 2* size set cys writes /flop ;
: raw ( an- ) #15 swap 2* 2* w/c #-1 + + w/c / writes /flop ;
: get ( a ) size @ #3 + 2/ 2/ cys reads /flop ;
: .com #0 #63 blocks put ;

\ Block 91
\
\ : blks n-n ( size in blocks to words )
\ : w/c -n ( words per cylinder )
\ : buffer -a ( 1 cylinder required for floppy dma )
\ : size -a ( locate size of 2nd file. Floppy has first FILLER then FILE allocated. FILLER is 2048 bytes, to fill out cylind
\ er 0. Names at most 8 letters, all caps. Directory starts at ) buffer $0980 +
\ : set n ( size. FILE must be larger than your file. )
\ : cys n-nn ( starting cylinder 1 and number of cylinders )
\ : raw an ( write raw data to cyl 15 , block 270 )
\ : put an ( write file from address )
\ : get a ( read file to address )

\ Block 92

```

```

( App: North Bridge ) empty macro
: 4@ dup $ED 1, ;
: 4! $EF 1, drop ; forth #2048 MagentaV dev
: nb $00 dev ! ;
: sb $3800 dev ! ;
: agp $0800 dev ! ;
: ess $6800 dev ! ;
: ric $7800 dev ! ;
: win $8000 dev ! ;
: ati $00010000 dev ! ;
: add $0CF8 a! 4! $0CFC a! ;
: q $80000000 + add 4@ ;
: en $8004 q #-4 and xor 4! ;
: dv dup $0800 * q swap #1 + ;
: regs dev @ #19 #4 * + #20 for dup q h. space dup h. cr #-4 + next drop ;
: devs #0 #33 for dup q dup #1 + drop if dup h. space drop dup #8 + q dup h. space over h. cr then drop $0800 + next drop
;
: ok show black screen text regs keypad ;
: ko show black screen text devs keypad ;
: u $40 dev +! ;
: d #-64 dev +! ;
: test $FF00 + a! 4@ ; ok

\ Block 93
\ ( Display the PCI interface chip registers )

\ Block 94
( ASCII )
: cf-ii string ( 0*00 ) $6F747200 , $696E6165 , $79636D73 , $7766676C , ( 0*10 ) $62707664 , $71757868 , $33323130 , $37363534
, ( 0*20 ) $2D6A3938 , $2F7A2E6B , $2B213A3B , $3F2C2A40 , ( 0*30 ) $4F545200 ,
: ch $FFFFFFF0 and unpack cf-ii + 1@ $FF and ;
: ii-cf string ( 0x20 ) $64632A00 , $7271706F , $2B2D6E6D , $2725232E , ( 0x30 3210 ) $1B1A1918 , ( 7654 ) $1F1E1D1C , ( ..98
) $28292120 , $2F6C6B6A , ( 0x40 CBA@ ) $3A43352C , ( GFED ) $3D3E3440 , ( KJIH ) $54523744 , ( ONML ) $3336393C , (
0x50
SRQP ) $38314742 , ( WVUT ) $3F414632 , ( .ZYX ) $58563B45 , $75745973 , ( 0x60 cba. ) $0A130576 , ( gfed ) $0D0E0410 , (
kjih
) $24220714 , ( onml ) $0306090C , ( 0x70 srqp ) $08011712 , ( wvut ) $0F111602 , ( .zyx ) $77260B15 , $62617879 ,
: chc $FFFFFFE0 + ii-cf + 1@ $FF and ;
: tst #2000 block dup #4 * #-1 + $60 for $01 + $80 i negate + over 1! next drop dump ; #51 MagentaV qch
: rr ( c-c ) qch ! $20 $60 for $01 + dup chc qch @ negate + drop 0! if pop drop ; then next $7F and ;

\ Block 95
\ ( Convert colorforth chars to and from ASCII )
\ : cf-ii ( conversion table )
\ : ch ( convert colorforth character to ASCII )
\ : ii-cf ( conversion table )
\ : chc ( convert ASCII to colorforth )
\ : tst ( create a table of ASCII characters )
\ : r ( scan the ii-cf table to perform cf-ii . Used to cross-reference the two tables )
\ : info ( display the ASCII version information in the last 64 bytes of block 11 . Type u to see more . )
\ ( dump takes a byte address )

\ Block 96
( App: RTC Real Time Clock ) empty

: bcd ( -c ) rtc@ #16 /mod #10 * + ;
: hms ( -n ) lo #4 bcd #100 * #2 bcd + #100 * #0 bcd + ; s
: ymd ( -n ) lo #9 bcd #2000 + #100 * #8 bcd + #100 * #7 bcd + ;
: day ( -c ) lo #6 bcd ;
: crlf ( Port Dump )
: one ( n-n ) space yellow dup rtc@ h.2 blue space dup . cr ;
: lines ( sn- ) for one #-1 + next drop ;
: ok show page text cr #15 #16 lines white cr ymd .
hms . day . keypad ;
: h
keypd nul nul quit nul nul nul nul
nul nul nul nul nul nul nul nul
nul nul nul nul nul nul nul nul
nul nul nul nul nul
$00250000 , #0 , #0 , #0 , #0 , #0 , #0 ,
ok

```

```

\ Block 97
\ ( RTC Real Time Clock )
\ : . ( displays the PC clock registers )
\ : bcd bcd-n ( bcd to binary )
\ : hms -n ( hours+mins+secs )
\ : ymd -n ( year+month+day )
\ : day -n ( day of the week )
\ : rtc ( display the Real Time Clock registers )
\ : one ( display one line )
\ : lines ( display n lines starting at s )
\ : ok ( display task )

\ Block 98
( LAN ) empty $03F8 nload init
: no block #4 * #1024 ;
: send no for dup 1@ xmit #1 + next drop ;
: receive no for rcv over 1! #1 + next drop ;
: no #18 #7 #18 * ;
: backup no for dup send #1 + next drop ;
: accept no for dup receive #1 + next drop ;

\ Block 99
\

\ Block 100
( Serial 3f8 2e8 1050 ) macro
: 1@ $8A 2, ;
: 1! a! $0288 2, drop ; forth
: r #0 + + ;
: 9600 #12 ;
: 38400 #3 ;
: 115200 #1 ;
: b/s $83 #3 r p! 38400 #0 r p! #0 #1 r p! #3 #3 r p! ;
: init b/s ( 16550 ) #1 #2 r p! #0 #4 r p! ;
: xmit ( n ) #5 r p@ $20 and drop if #0 r p! ; then pause xmit ;
: cts #6 r p@ $30 and $30 xor drop if cts ; then xmit ;
: st #6 r p@
: xbits $30 and $10 / dup #1 and 2* 2* + 2/ ;
: st! #4 r p! ;
: ?rcv #5 r p@ #1 and drop if #0 r p@ then ;
: rcv ?rcv if ; then pause rcv ; blk @ edit

\ Block 101
\
\ : 1@ a-n ( fetch byte from byte address )
\ : 1! na ( store byte to byte address )
\ : r n-p ( convert relative to absolute port address. Base port on stack at compile time. Compiled as literal at yellow
\green transition )
\ : 9600
\ : 115200 ( baud-rate divisors. These are names, not numbers )
\ : b/s ( set baud rate. Edit to change )
\ : init ( initialize uart )
\ : xmit n ( wait for ready and transmit byte )
\ : cts n ( wait for clear-to-send then xmit )
\ : st -n ( fetch status byte )
\ : xbits n-n ( exchange status bits )
\ : st! n ( store control byte )
\ : ?rcv ( fetch byte if ready. Set flag to be tested by ) if
\ : rcv -n ( wait for ready and fetch byte )

\ Block 102
( App: Colors ) empty
#4210752 MagentaV col #4210752 MagentaV del
: lin dup 2/ 2/ dup 2* line ;
: hex xy @ #7 and over 2/ for lin #7 + next over for lin next swap 2/ for #-7 + lin next drop ;
: +del del @ nop
: petal and col @ + $00F8F8F8 and rgb color #100 hex ;
: -del del @ $00F8F8F8 xor $00080808 + ;
: rose #0 +del #-176 #-200 +at $00F80000 -del petal #352 #-200 +at $00F80000 +del #-264 #-349 +at $F800 -del petal #176 #-200
+at $F8 +del #-176 #98 +at $F8 -del petal #176 #-200 +at $F800 +del ;

```

```
: ok show page #512 #282 at rose text col @ h. space del @ $FF and h. keypad ; nload ok h e
```

```
\ Block 103
\ ( Draws 7 hexagons. Colors differ along red, green and blue axes. )
\ : col ( color of center hexagon )
\ : del ( color difference )
\ : lin n ( draws 1 horizontal line of a hexagon )
\ : hex n ( draws top, center and bottom. Slope 7 x to 4 y is 1.750 compared to 1.732 )
\ : +del n ( increment color )
\ : -del n
\ : petal n ( draw colored hexagon )
\ : rose ( draw 7 hexagons )
\ : ok ( describe screen. Center color at top )
```

```
\ Block 104
( Colors keypad )
: in del @ 2* $00404040 min del ! ;
: out del @ 2/ $00080808 max del ! ;
: r $00F80000
: +del del @
: +col and col @ + $00F8F8F8 and col ! ;
: g $F800 +del ;
: b $F8 +del ;
: -r $00F80000 -del +col ;
: -g $F800 -del +col ;
: -b $F8 -del +col ;
: nul ;
: h keypd nul nul quit nul -r -g -b nul r g b nul out nul nul in nul nul nul nul nul nul nul nul $00250000
, $00626772 dup , , $2B00002D , #0 , #0 , #0 ,
```

```
\ Block 105
\
\ : in ( increment color difference )
\ : out ( decrement it )
\ : r
\ : g
\ : b ( increment center color )
\ : -r
\ : -g
\ : -b ( decrement it )
\ : +del ( redefine with ; )
\ : +col ( change center color )
\ : nul ( ignore )
\ : h ( describe keypad )
```

```
\ Block 106
( App: Wood ) empty #125810090 MagentaV x #-1123891786 MagentaV y
#8286477 MagentaV inc #33554432 MagentaV frame #39 MagentaV dep #65056 MagentaV hole
: h0 #400000 inc ! #15 dep !
: home inc @ scrnw #2 / * negate x s ! inc @ scrnh #2 / * y ! ; macro
: f* $2EF7 2, #26 shr $E2C1 2, #6 1, $C20B 2, nip ;
: w! a! $00028966 3, drop ; forth
: wf+ frame @ w! #2 frame +! ;
: om negate $FF + ; o5 om $03 shr $07E0 xor ;
: o4 $FC and #3 shl $1F xor ;
: o3 om $F8 and #8 shl $1F xor ;
: o2 #3 shr $F800 xor ;
: o1 om $FC and #3 shl $F800 xor ;
: o0 $F8 and #8 shl $07E0 xor ;
: order jump o0 o1 o2 o3 o4 o5 o0
: hue #8 shl #26 / dup $FF and swap #8 shr order ;
: vlen dup f* swap dup f* + ;
: vdup over over ;
: vndp push push vdup pop pop ;
: itr over dup f* over dup f* negate + push f* 2* pop swap v+ over 2* + 2/ vndp + + ;
: data ; #4 +load ok draw h
```

```
\ Block 107
\ ( Display an imitation pine blockboard screen )
\
\ ( This is based on a skewed Mandelbrot set with )
```

\ (modified colors)

\ Block 108

(App: Mandelbrot Set) empty

#-204800000 MagentaV x #153600000 MagentaV y #400000 MagentaV inc

#34 MagentaV dep #33554432 MagentaV frame #0 MagentaV hole

: h0 #400000 inc ! #34 dep !

: home inc @ scrnw #2 / * negate x s ! inc @ scrnh #2 / * y ! ; macro

: f* \$2EF7 2, #26 shr \$E2C1 2, #6 1, \$C20B 2, nip ;

: w! a! \$00028966 3, drop ; forth

: wf+ frame @ w! #2 frame +! ;

: hue (n-n) #8191 * ; dup dup + dup dup + + dup dup + dup dup ef + + ; #3142 * ; @ ; ef

: vlen dup f* swap dup f* + ;

: vdup over over ;

: vndp push push vdup pop pop ;

: itr over dup f* over dup f* negate + push f* 2* pop swap v+ ;

: x: (c-) emit \$3D emit ;

: data text #0 #0 at \$78 x: x @ . \$79 x: y @ . \$69 x: inc @ . \$64 x: dep @ . ; nload ok draw h

\ Block 109

\

\ Block 110

(Mandelbrot Set)

: o 0 0 dep @ #1 max for vndp itr vdup vlen \$F0000000 + drop -if *next drop drop hole @ ; then drop drop pop hue ;

: mh x @ swap scrnw for o wf+ inc @ u+ next nip ;

: mv y @ scrnh for mh inc @ negate + next drop ;

: +d #2 dep +! : -d #1 dep +! dep @ #1 max dep !

: draw vframe frame ! mv data ;

: ok c show keypad ;

: l inc @ scrnw #1 - #8 * / negate x +! draw ;

: u inc @ scrnh #1 - #8 * / y +! draw ;

: d inc @ scrnh #1 - #8 * / negate y +! draw ;

: r inc @ scrnw #1 - #8 * / x +! draw ;

: +z inc @ #3 max dup scrnw #1 - #8 * / x +! dup scrnh #1 - #8 * / negate y +! #3 #4 * / #3 max inc ! draw ;

: -z inc @ #10000000 min dup scrnw #1 - #8 * / negate x +! dup scrnh #1 - #8 * / y +! #4 #3 * / inc ! draw ;

: hh home draw ; : hh2 h0 draw ;

: h keypd nul nul quit nul -d nul nul +d l u d r -z hh hh2 +z nul nul nul nul nul nul nul nul nul nul \$2500 , \$2B00002D , \$13121110 , \$2B30482D , #0 , #0 , #0 ,

\ Block 111

\ (More Mandelbrot)

\ (ludr move the cursor left right up down)

\ (- + top row change depth detail)

\ (- + bottom row change zoom)

\ (h centres the image to the home location)

\ (0 resets depth and zoom)

\ Block 112

(Sandbox o98 any old ASCII ovk@)

: rrrr push ;

: tttt pop ;

: test (your code here) ;

\ Block 113

\ (Help screen)

\ (F1) show this help screen or the start shadow

\ (F2) toggle number base between decimal and hex

\ (F3) toggle seeb display of blue words (-) blue

\ (F4) editor, toggle colorforth / colorblind mode

\ (F5) rsn...

\ (F6) shows the last block edited

\ Block 114

(App: Sounds make a noise) empty

#25 MagentaV tempo #0 MagentaV mute #2259 MagentaV period

: tn (ft-) tempo @ * swap #660 #50 */


```

: hz ( tf- ) push #1000 #1193 pop */
: osc ( tp- ) dup period ! split $42 p! $42 p!
: tone ( t- ) mute @ #0 + drop if drop ; then $4F $61 p! ms $4D $61 p! #20 ms ;
: click #1 #90 osc ;
: t #3 tn ;
: q #8 tn ;
: c #16 tn ;
: 2tone #75 q #50 q ;
: h1 #50 c #54 q #50 q #45 c #60 c ;
: h2 #40 c #45 q #50 q #50 c #45 c ;
: h3 #54 c #60 q #54 q #50 c #45 q #40 q #50 t #45 t #50 t #45 t #45 #12 tn #40 q #40 #32 tn ;
: hh
: handel h1 h2 h3 ;
: piano #55 #7 for dup q #3 #2 */ next drop ;
: cetk #6 c #10 c #8 c #4 c #6 #32 tn ;
: bomb mute @ #0 + drop if ; then $4F $61 p! #500 for #1000 i invert + split $42 p! $42 p! #1 ms next $4D $61 p! #1 #32 tn
; handel

```

```

\ Block 115
\ ( Sounds : using the PC internal speaker )
\ : tempo ( in ms per 1/8 quaver )
\ : mute ( equals -1 to disable sound )
\ : period ( test only - value sent to hardware )
\ : tn ( ft- play f Hz for t * 11 ms )
\ : hz ( tf- play t ms at f Hz )
\ : osc ( tp- play t ms of period p )
\ : tone ( t- play the current tone for t ms )
\ : click ( makes a click )
\ : t ( triplet )
\ : q ( quaver )
\ : c ( crotchet )
\ : 2tone ( 2 tones )
\ : h1
\ : h2
\ : h3
\ : hh
\ : handel ( part of Handels Gavotte )
\ : piano
\ : cetk ( Close Encounters of the Third Kind )
\ : bomb ( - well sort of .... )

```

```

\ Block 116
( Colourblind Editor Display )
#1 MagentaV state $01 MagentaV state*
: +txt white $6D emit space ;
: -txt white $6E emit space ;
: +imm yellow $58 emit space ;
: -imm yellow $59 emit space ;
: +mvar yellow $09 emit $11 emit $05 emit $01 emit space ;
: txs string $03010100 , $07060504 , $09090901 , $0F0E0D0C , ( ; )
: tx ( c-c ) $0F and txs + 1 @ $0F and ;
: .new state @ $0F and jump nul +imm nul nul nul nul nul nul +txt nul nul +mvar nul nul nul ;
: .old state* @ $0F and jump nul -imm nul nul nul nul nul nul -txt nul nul nul nul nul nul ;
here
: cb ( n-n ) #0 + 0if ; then tx
  state @ swap dup state ! - drop if .old .new
  state @ #0 + if dup state* ! then then ;
: cbs ( -- here ) #0 + $00 + cblind ! ;

```

```

\ Block 117
\
\ : state
\ : cb ( acts on a change of token type. It ignores extension tokens )

```

```

\ Block 118
( Graphics demo Todo: fix this! ) empty
#2 #22 +thru

```

```

: htm #116 load ( html ) ;
log1

```

```

\ Block 119
\ ( A graphics extension package )
\ : . ( Type ) ok ( after loading this block )

\ Block 120
( added macros ) forth
: mfill #24 for cr space #5 for rand32 h. space next next ;
: matrix show black screen green mfill keypad ;

\ Block 121
\ ( added macros )
\ : 1+ ( increment tos )
\ : 1- ( decrement tos )
\ : @b ( fetch byte from absolute addr. )
\ : @w ( fetch word from absolute addr. )
\ : @l ( fetch long from absolute addr. )
\ : !b ( store byte in absolute addr. )
\ : !w ( store word in absolute addr. )
\ : !l ( store long in absolute addr. )
\ : matrix ( What is the Matrix? )
\ : ver ( returns the address of the CFDOS version - use as ) ver dump

\ Block 122
( Stack juggling + misc. )
: v- ( v-v ) push invert 1+ u+ pop invert 1+ + ;
: vn push rot less if rot pop -rot ; then -rot pop ; #2222 MagentaV pen #236986408 MagentaV bs
: vloc ( xy-a ) scrnw 2* * over ++ vframe + ;
macro
: @w $8B66 3, ;
: !w a! $00028966 3, drop ;
forth
: point ( xy- ) pen @ swap w! ;
: at? ( -xy ) xy @ $00010000 /mod swap ;
: @r ( a-a ) 1+ dup #4 u+ @ + ;
: !r ( aa- ) 1+ dup push negate #-4 + + pop ! ;
: select ( an- ) #5 * over + @r swap @r !r ;

\ Block 123
\ ( Stack juggling words. small and fast. )
\ : addr -a ( absolute address )
\ : rot abc-bca ( stack pictures are best .. )
\ : -rot abc-cab ( ..described with letters, in )
\ : tuck ab-bab ( ..this case. )
\ : 2swap abxy-xyab
\ : 2over abxy-abxyab
\ : 2dup ab-abab
\ : v- v1v2 - v1-v2 ( vector subtract. )
\ : vn vv-vv ( sort vectors so x1 is less x2 )
\ : vframe -addr ( address of screen. )
\ : pen -addr ( current color. )
\ : bs -addr ( base for elements )
\ : vloc xy-a ( convert xy into addr. )
\ : point xy- ( set point at xy to current pen. )
\ : at? -xy ( return current screen location. )
\ : @r a-a ( get absolute addr from jump/call )
\ : !r aa- ( set jump/call to absolute addr. )
\ : select an- ( select call n from table a. Store it in table call 0 )

\ Block 124
( new logo )
: .co $72 $6F $6C $6F $63 5* ;
: .fo $68 $74 $72 $6F $46 5* ;
: cf #27 dup at silver .co .fo #25 dup at red .co green .fo ;
: log1 show black screen text cf keypad ;
: ckb black #0 #740 at #1023 #767 box #800 #650 at #1023 #740 box ;
: grads #0 #128 for i 2* 1- rgb color dup #10 at #5 + dup #120 box next
  iconw #21 * - #128 for #257 i 2* negate + dup #256 * + rgb color dup #10 at #5 + dup #100 box next drop ;

\ Block 125
\ ( New logo )
\ : log1 ( a simple text demo )

```

```
\ : ok ( the graphics demo )
```

```
\ Block 126
```

```
( Circles ) #-16977 MagentaV c-cd #0 MagentaV c-ff
```

```
: point4 #4096 * swap #4 * 2dup + 2/ negate bs @ + pen @ over w! over push + pen @ over w! + pen @ over w! pop negate + pen @ swap w! ;
```

```
: opnts 2dup point4 2dup swap point4 ;
```

```
: d? c-cd @ ?f drop -if ; then dup invert c-cd +! 1- #1 c-ff ! ;
```

```
: cfl 1+ 1+ push pen @ swap pop 2/ for over over w! 1+ 1+ next drop drop ;
```

```
: cfl4 #4096 * swap #4 * 2dup + 2/ negate bs @ + swap 2dup cfl push + pop cfl ;
```

```
: fvr ?f drop if cfl4 #0 c-ff ! ; then point4 ;
```

```
: fpnts 2dup c-ff @ fvr 2dup swap cfl4 ;
```

```
: points opnts ;
```

```
: addr pop ;
```

```
: pntst addr points opnts fpnts ;
```

```
: framed pntst #1 select ;
```

```
: filled pntst #2 select ;
```

```
: circle ( rxc- ) #0 c-ff ! pen ! #1024 * + 2* vframe + bs ! #0 swap dup negate c-cd !
```

```
: crcl less if points #1 u+ over c-cd +! d? crcl ; then points drop drop ;
```

```
\ Block 127
```

```
\ ( Circles )
```

```
\ : point4 ( .. all other words are internal. )
```

```
\ : points ( acts like a deferred word. )
```

```
\ : pntst ( table of calls to different point routines. Select alters ) points
```

```
\ : framed ( set ) circle ( to draw outlined circles. )
```

```
\ : filled ( set ) circle ( to draw filled circles. )
```

```
\ : circle rxc- ( draw circle with radius ) r ( center ) xy ( in color ) c
```

```
\ Block 128
```

```
( lines )
```

```
#-1456 MagentaV ax #0 MagentaV ay #2048 MagentaV sx #2 MagentaV sy #31987278 MagentaV lbase
```

```
macro
```

```
: lp $B909090 , $C88BADE8 , $205A8BAD , $232B8966 , $030578C0 , $185A0302 , $03084203 , $ECE2105A , ;
```

```
forth
```

```
: !base ( xy- ) #2048 * over + + vframe + lbase ! ;
```

```
: bline ( xy- ) abs 2* dup ay ! over 2* negate ax ! over
```

```
negate + swap 1+ pen @ ax a! lp drop ;
```

```
: ?xd ( vv-vv ) 2over 2over v- abs swap abs swap less
```

```
drop drop #1 if 1+ then ?f drop ;
```

```
: !sy ( yn-y ) push ?f pop -if negate then sy ! bline ;
```

```
: xdom ( xyxy- ) 2swap !base #2 sx ! #2048 !sy ;
```

```
: ydom ( xyxy- ) swap 2swap swap !base swap #2048 sx !
```

```
#2 !sy ;
```

```
: aline ( vv- ) ?xd if vn 2over v- xdom ; then push push
```

```
swap pop pop swap vn 2over v- ydom ;
```

```
: line ( xy- ) at? 2over aline at ;
```

```
: frame ( xy- ) at? 2over drop over line 2over line 2swap
```

```
push drop over pop line line ;
```

```
\ Block 129
```

```
\ ( line drawing Do Not Mess With Variables. They are indexed by lp. )
```

```
\ : lp ( macro inner loop for speed. Draws point and moves location. )
```

```
\ : !base x y -- ( set base address )
```

```
\ : bline dx dy -- ( draw a line using bresenham x dominant )
```

```
\ : ?xd v1 v2 -- v1 v2 ( set flag if line is x-dominant )
```

```
\ : !sy dy n -- dy ( store n in sy set sign to match sign of dy )
```

```
\ : xdom x y dx dy ( draw an x-dominant line )
```

```
\ : ydom x y dx dy ( draw a y-dominant line )
```

```
\ : aline v1 v2 ( draw any straight line )
```

```
\ : line x y ( draw line from current at to xy. Moves at to given xy. )
```

```
\ : frame xy- ( trace outline of rectangle with corners at and xy. Pen position is not altered. )
```

```
\ Block 130
```

```
( Utils )
```

```
: xxcoy ( sf st ) $E7C1F88B , $368B560A , $B90AE6C1 , $0100 , $AD5EA5F3 , $C3AD 2,
```

```
: xrcopy ( sf sl st ) push dup push swap negate + pop swap pop over + swap for over over copy push 1- pop 1- -next drop drop
```

```
;
```

```
\ Block 131
```

```
\ ( Utils )
```

```
\ : copy from to- ( copy from to block numbers. Unlike orig copy; no change to blk )
\ : rcopy first last to- ( multiple block copy routine )
```

```
\ Block 132
( fillstack ) #1114112 MagentaV fstak $00 MagentaV fstakn
: fstini ( - ) $0400 block fstak ! 0 fstakn ! ;
: fpop ( -uuu ) fstak @ #3 for dup @ swap cell- next
  fstak ! #-3 cells fstakn +! ;
: fpsh ( uuu- ) #3 for cell fstak +! fstak @ ! next
  #3 cells fstakn +! ;
: fst? ( - ) fstakn @ ?f drop ; fstini
macro
: 2- 1- 1- ;
: 2+ 1+ 1+ ;
forth
: 5drop ( uuuuu- ) drop drop drop drop drop ;
: rtre ( a-n ) #2048 #1 - and negate #2048 + ;
: enstak ( dlrlr-dlrlr ) 2- #4 pick dup #3 pick + over
  #3 pick + fpsh over #4 pick negate + 2+ drop
  -if #4 pick negate dup #3 pick +
```

```
\ Block 133
\ ( fillstack: stack of spans to fill. )
\ : fstini ( initialize )
\ : fpop ( pop the next element from the stack )
\ : fpsh ( push element on the stack )
\ : fst? ( set 0 flag if empty )
\ : 2- ( screen pixels are 2 bytes. )
\ : 2+
\ : 5drop ( unload forth stack. )
\ : rtre a-n ( return remaining to right screen edge. )
\ : enstak dlrlr-dlrlr ( push a span or element onto the stack. Also push a left hand direction reversal and a right hand
\ reversal if needed. )
```

```
\ Block 134
( area filling ) #25702 MagentaV tfc #14660 MagentaV fc
: pset ( a-f ) dup dup w@ $FFFF and tfc @ negate + drop
  if drop 0 ; then fc @ swap w! 0 1+ ;
: bcup ( a-a ) dup #2048 #1 - and 2- begin -if drop ; then
  push 2- pset drop pop if 2- *end then drop 2+ ;
: ispan pset if ; then push enstak pop ;
: xgr dup negate #3 pick + drop ;
: nispan ( dlrlx- ) xgr -if 5drop pop pop pop drop drop
  drop ; then pset if push nip dup pop then ;
: dosp ( dlrlx-dlrlxi ) jump nispan ispan ;
: sha2 over rtre begin ( dlrlxic ) -if drop ; then push
  dosp #2 u+ pop 2- end
: sha1 ( dlr- ) over pset over ( dlrxil ) if bcup ( dlrxil ) then
  swap push swap 2+ pop ( dlrlxi ) sha2 ?f drop
  if enstak then 5drop ;
: sha begin fst? if fpop sha1 *end then ;
: fsln ( a-lr ) dup bcup swap dup rtre
  begin -if drop ; then push pset drop if
  2+ pop 2- *end then pop drop 2- ;
: afill ( xyc- ) fstini fc ! vloc dup w@ $FFFF and tfc !
  fsln over over #-2048 u+ #-2048 + #-2048 -rot fpsh
  #2048 u+ #2048 + #2048 -rot fpsh sha ;
: afill drop drop drop ;
```

```
\ Block 135
\ ( area filling )
\ : pset a-0/1 ( set pixel at a, if pixel equals tfc. Return 0 if not, 1 if pixel was set. )
\ : bcup a-a ( adjust a until left edge is found. Limited to screen edge. )
\ : ispan ( stack if the right edge is found. )
\ : xgr ( Set neg flag if x is greater then parent-r )
\ : nispan ( exit if beyond right edge of span, else start a new span. )
\ : dosp dlrlx - dlrlxi ( jump table. )
\ : sha2 ( let x go over each pixel and set it or start/end new spans. )
\ : sha1 ( starting at left edge, find the new left edge and init x to next pixel. stack if run into right screen edge while
\ in span. )
\ : sha ( pop the next span and color it. )
```

```

\ : fsln a-lr ( Starting at screen address a, find the left edge and right edge of the seed line. Color it in the proces
\s. )
\ : afill xyc ( starting with screen location xy, and color c, fill the color found there with c until the color found change
\ s. )

\ Block 136
( random ) #-1896373196 MagentaV rsav #-526774649 MagentaV rseed
: rand ( -- ) time rsav ! $E09A0E87 rseed ! ;
: ror ( u-u ) $D3ADC88B , $C3C8 2,
: random ( w-w ) push rseed @ #0 #32 for 2* swap 2* swap -if rsav @ xor then next nip #15 ror dup rsav ! abs pop mod abs
; rand
: tt $0100 random ;

\ Block 137
\ ( random )
\ : rand - ( set random variables )
\ : ror nm-n ( rotate n m times right )
\ : random n-0..n-1 ( return a random number range 0..n-1 limited to a 16 bit number. )

\ Block 138
( demos )
: xlate #384 + #512 u+ ;
: xat xlate at ;
: xline xlate line ;
: 4lines over #0 xat #0 over xline over - #0 xline negate #0 swap xline #0 xline ;
: art #70 for #71 i - #5 * i #5 * 4lines next ;
: radius #8 ;
: lrc push dup dup + negate pop + random + ;
: shade 2over #2 + 2over drop #3 + #0 circle circle ;
: dotted filled #100 for radius random dup #397 lrc #621 + over #176 lrc #121 + $FFFF random shade next ;
: blbx black #6 #121 at #404 #299 box ; #-17 MagentaV xyzz
: fillit #-1 xyzz +! xyzz @ #200 + drop -if blbx 0 xyzz ! then framed #3 for #8 random #2 + dup #398 lrc #6 + over #178 lrc
#121 + $FFFF circle next
; #6 #210 $FFFF0 random afill ;

\ Block 140
( new logo 2 )
: lnes framed #20 for i 2* #40 + #250 #584 $FF07 circle next filled #30 #250 #584 $F800 circle framed $FFFF pen ! #620 #120
at #1020 #300 frame #5 #120 at #405 #300 frame ;
: ok show black screen grads lnes text cf dotted fillit ckb keypad ; ( ok )

\ Block 141
\ ( New logo )
\ : log1 ( a simple text demo )
\ : ok ( the graphics demo )

\ Block 142
( html0 ) #80 load #2222119 MagentaV h-dd #0 MagentaV ppt macro
: 2/s ?lit $E8C1 2, 1, ; forth
: temit h-dd @ !b #1 h-dd +! ;
: tspace $20 temit ;
: .dc ?f #1 -if - then swap abs
: dcl #10 /mod swap $30 + push ?f 0if drop ?f drop -if $2D temit then pop temit ; then dcl pop temit nop ;
: .hx $39 over #15 and $30 + less nip if $27 + then push #4 2/s 0if drop pop temit ; then .hx pop temit nop ;
: strt dup @b $FF and if temit 1+ strt ; then drop drop ;
: str: pop strt ;
: header str: $6D74683C , $3C0A3E6C , $6B6E696C , $6C657220 , $7974733D , $6873656C , $20746565 , $65707974 ,
$6574223D ,
$632F7478 , $20227373 , $66657268 , $3D 1, $6C6F6322 , $6F66726F , $2E687472 , $22737363 , $703C0A3E , $0A3E 3,
: trailer str: $74682F3C , $0A3E6C6D , $00 1,

\ Block 143
\ ( html0. Block 80 has ascii conversion tables. )
\ : h-dd ( data destination. ) ppt ( pre- parsed type. )
\ : 2/s ( macro, right shift by n. )
\ : temit c- ( emit char to target. )
\ : tspace ( emit space )
\ : .dc n- ( signed decimal print. Recursive! )
\ : dcl ( dec print loop. )
\ : .hx n- ( unsigned hex print. Also recursive. Both routines have no leading zeroes. )
\ : strt a- ( Print bytes from address until first null byte. )

```

```
\ : str: ( Output what follows up to null byte. )
\ : header ( Lay down html header to display blocks. The header is very minimal. It expects colorforth.css in the same direct
\ory. )
\ : trailer ( Closing html stuff. )
```

```
\ Block 144
( html1 )
: .code 1- drop -if ; then str: $6F632F3C , $003E6564 ,
: .all str: $646F633C , $6C632065 , $3D737361 , $00 1,
: same? ppt @ over ppt ! swap over - 1+ + drop ;
: comn same? 0if drop tpc pop drop ; then .code .all ;
: .def str: $3E666564 , $20 2,
: .com #2 comn str: $3E6D6F63 , $20 2,
: .chx #3 comn str: $3E786863 , $20 2,
: .exe #4 comn str: $3E657865 , $20 2,
: .xhx #5 comn str: $3E786878 , $20 2,
: .cpm #6 comn str: $3E6D7063 , $20 2,
: .var #7 comn str: $3E726176 , $20 2,
: .txt #8 comn str: $3E747874 , $20 2,
: .txc #9 comn str: $3E637874 , $20 2,
: .tac #10 comn str: $3E636174 , $20 2,
```

```
\ Block 145
\ ( html1 )
\ : .code n- ( output /code in brackets if n is larger then 0. )
\ : .all ( common part to start a new code tag. )
\ : same? n-o ( set ppt to the new type. Return the old type with flags set from comparison. )
\ : comn n- ( if this is a new tag, close prev tag and print common part. If not: print space AND EXIT CALLER )
\ : .def ( Each of these words correspond to a )
\ : .com ( .. code tag as defined in colorforth.css )
\ : .chx ( .. The numbers are positional, and bare )
\ : .exe ( .. no correspondence to the pre parsed )
\ : .xhx ( .. types. They will output if a change )
\ : .cpm ( .. in tag is required. Comn will exit )
\ : .var ( .. by doing a pop-drop if the tag is the )
\ : .txt ( .. same. )
\ : .txc
\ : .tac
```

```
\ Block 146
( html2 )
: .str ch if termit .str ; then drop drop ;
: bs1 #0 ppt ! str: $3E72683C , $6C627B0A , $206B636F , $00 1,
: bs2 str: $643C0A7D , $63207669 , $7373616C , $786F623D , $0A3E 3,
: bend ppt @ .code str: $69642F3C , $000A3E76 ,
: .br 1- drop -if ; then str: $3E72623C , $0A 2,
: pp0 .str ;
: pp1 .exe .str ;
: pp3 ppt @ dup .code .br #1 ppt ! .all .def .str ;
: pp4 .com .str ;
: pp7 .cpm .str ;
: pp9 .txt .str ;
: ppa .txc .str ;
: ppb .tac .str ;
: ppc .var .str 1+ dup @ .com .dc ;
```

```
\ Block 147
\ ( html2 )
\ : .str n- ( Unpack n and print as ascii. )
\ : bs1 ( clear the type and print html stuff for the start of a block. )
\ : bs2 ( second half of block header. )
\ : bend ( Block end html stuff. )
\ : .br n- ( Html line break, if n larger then 0 )
\ : pp0 ( The preparsed words in a block are )
\ : pp1 ( .. printed by the ppn words. Eg pp0 is )
\ : pp3 ( .. word continuation pp1 is for executed )
\ : pp4 ( .. words, etc. They unpack and print. )
\ : pp7 ( .. They also print html tags. )
\ : pp9
\ : ppa
\ : ppb
```

\ : ppc

\ Block 148

(html3)

```
: dbn push 1+ dup @ pop ?f drop ;
: sln dup 2/ 2/ 2/ 2/ swap #16 and drop ;
: xnb if .xhx .hx ; then .exe .dc ;
: cnb if .chx .hx ; then .com .dc ;
: pp2 dbn xnb ;
: pp5 dbn cnb ;
: pp6 sln cnb ;
: pp8 sln xnb ;
: ppdo jump pp0 pp1 pp2 pp3 pp4 pp5 pp6 pp7 pp8 pp9 ppa ppb ppc ;
: index dup #15 and dup push or pop ;
: dblk dup bs1 .dc bs2 block begin dup @ ?f 0if drop drop bend ; then index ppdo 1+ end
: hbuf #2000 block ;
: html hbuf #4 * h-dd ! header swap over for over i - 1+ + over + dblk next drop drop trailer hbuf h-dd @ #3 + #4 / over
- 1+ + #3 for tpsc next ;
```

\ Block 149

(html3)

```
\ : dbn an-an ( Fetch next word. Set hex flag. )
\ : sln n-n ( Make full word and set hex flag. )
\ : xnb n- ( print n as hex/dec executed number. )
\ : cnb n- ( print n as hex/dec compiled number. )
\ : pp2 an-a ( A double executed number. )
\ : pp5 an-a ( A double compiled number. )
\ : pp6 n- ( A single compiled number. )
\ : pp8 n- ( A single executed number. )
\ : ppdo ( Table of words. The index is the pre- parsed type type. )
\ : index n-ni ( extract index from n. )
\ : dblk b- ( print block b in html. )
\ : hbuf -a ( start of buffer. )
\ : html bn-al ( Output n blocks starting with block b in html. Leaves addr and length on the stack, so it can be saved using
\ ) file put ( on a floppy. )
```

\ Block 150

(html3)

```
: dbn push 1+ dup @ pop ?f drop ;
: sln dup 2/ 2/ 2/ 2/ swap #16 and drop ;
: xnb if .xhx .hx ; then .exe .dc ;
: cnb if .chx .hx ; then .com .dc ;
: pp2 dbn xnb ;
: pp5 dbn cnb ;
: pp6 sln cnb ;
: pp8 sln xnb ;
: ppdo jump pp0 pp1 pp2 pp3 pp4 pp5 pp6 pp7 pp8 pp9 ppa ppb ppc ;
: index dup #15 and dup push or pop ;
: dblk dup bs1 .dc bs2 block begin dup @ ?f 0if drop drop bend ; then index ppdo 1+ end
: hbuf #2000 block ;
: html hbuf #4 * h-dd ! header swap over for over i - 1+ + over + dblk next drop drop trailer hbuf h-dd @ #3 + #4 / over
- 1+ + #3 for tpsc next ;
```

\ Block 151

(html3)

```
\ : dbn an-an ( Fetch next word. Set hex flag. )
\ : sln n-n ( Make full word and set hex flag. )
\ : xnb n- ( print n as hex/dec executed number. )
\ : cnb n- ( print n as hex/dec compiled number. )
\ : pp2 an-a ( A double executed number. )
\ : pp5 an-a ( A double compiled number. )
\ : pp6 n- ( A single compiled number. )
\ : pp8 n- ( A single executed number. )
\ : ppdo ( Table of words. The index is the pre- parsed type type. )
\ : index n-ni ( extract index from n. )
\ : dblk b- ( print block b in html. )
\ : hbuf -a ( start of buffer. )
\ : html bn-al ( Output n blocks starting with block b in html. Leaves addr and length on the stack, so it can be saved using
\ ) file put ( on a floppy. )
```

\ Block 152

```
( simpler and slower bresenham line drawing. For reference. ) #360 MagentaV ax #0 MagentaV ay #2 MagentaV sy #0 MagentaV
sw
```

```
: bpoint push 2dup sw @ ?f drop if swap then point pop ;
: bline abs 2* dup ay ! over 2* negate ax ! over negate + swap 1+ for bpoint ?f +if sy @ u+ ax @ + then ay @ + push #1 u+
pop next drop drop drop ;
: ?xd 2over 2over v- abs swap abs swap less drop drop #-1 if 1+ then ?f drop ;
: !sy push ?f pop -if negate then sy ! bline ;
: xdom #0 sw ! #1 !sy ;
: ydom #1 sw ! #1 !sy ;
: aline ?xd if vn 2over v- xdom ; then push push swap pop pop swap vn 2over v- ydom ;
```

```
\ Block 154
```

```
\ Block 155
```

```
\ ( fillstack: stack of spans to fill. )
\ : fstini ( initialize )
\ : fpop ( pop the next element from the stack )
\ : fpsh ( push element on the stack )
\ : fst? ( set 0 flag if empty. )
\ : pick ( copy n from the stack. )
\ : 2- ( screen pixels are 2 bytes. )
\ : 2+
\ : 5drop ( unload forth stack. )
\ : rtre a-n ( return remaining to right screen edge. )
\ : enstak dlrlr-dlrlr ( push a span or element onto the stack. Also push a left hand direction reversal and a right hand
\ reversal if needed. )
```

```
\ Block 160
```

```
( Timing ) empty macro
: out $E1E6 2, ; forth
: tare time invert #1000 for next time + ;
: tare+ time invert push #1000 for dup next c pop time + ;
: test + s #1000 for out next time + ; ( next 3 loop 5.7 /next 2 /swap 25 swap 7.2 ) macro
: c! $C88B 2, drop here ;
: loop $49 1, $75 1, ( e2 ) here invert + 1, ; forth
: try time invert #1000 c! loop time + ;
```

```
\ Block 162
```

```
( Spy ) empt $03F8 #54 load init
: ry #5 r p@ ; nload init
: buffer #2000 block ; #2000 #1 wipes #0 MagentaV buf #0 buf !
: b! swap $FF and + buf @ buffer + ! #1 buf +! ;
: dev r2 if dup xmit $0100 b! dev ; then ;
: pc ?rcv if dup x2 0 b! pc ; then ;
: relay s2 st s2! st! dev pc ;
: .1 $0F and digit ;
: .byte dup $10 / .1 .1 ;
: traffic text buffer buf @ #1 max #400 min for dup @ green $0100 ? if red then .byte #1 + next drop ;
: ok show black screen relay traffic keyboard ;
: k show black screen relay keyboard ;
: q #6000 for relay next ;
: test st! st ; #84 load
```

```
\ Block 164
```

```
( Serial 2 )
: r $02F8 + ;
: b/s $83 #3 r p! 9600 #262 #0 r p! #0 #1 r p! #3 #3 r p! ;
: init b/s ( 16550 ) #1 #2 r p! #0 #4 r p! ;
: x2 #5 r p@ $20 and drop if #0 r p! ; then x2 ;
: c2 #6 r p@ $30 and $30 or drop if c2 ; then x2 ;
: s2 #6 r p@ xbits ;
: s2! #4 r p! ;
: r2 #5 r p@ #1 and drop if #0 r p@ ; then ;
```

```
\ Block 166
```

```
( Dynapulse 200m )
: send pop swap for dup 1@ x2 #1 + next drop ;
: reset #2 send $2323 ,
: 1st #12 send $37269A12 , $39027AFD , $23C75680 ,
```



```

\ Block 168
( Test sidt and lidt )
#7168 MagentaV vidt sidt vidt !
: resi cli vidt @ lidt ;

\ Block 169
\ ( This block is used by the next block as the interrupt vector table. )

\ Block 170
( Interrupts ) macro
: 1ld ( n ) ?lit $B9 1, , ;
: p! ( na ) a! $EE 1, drop ;
: 2push $5250 2, ;
: 2pop $585A 2, ;
: forth: 2push $00BE5651 3, ivec $0100 + a, ;
: ;forth $595E 2, 2pop ;
: clear $20E620B0 , ;
: 8clear $A0E620B0 , $20E6 2, ;
: i; $CF 1, ; forth
: interrupt ( n ) 2* 2* 2* ivec + here $FFFF and $00080000 + over ! here $FFFF0000 and $8E00 + swap #4 + ! ;
: ifill ( an ) for dup interrupt #1 + next drop ; $00 $70 ifill
: ignore i; $20 $08 ifill
: ignore 2push clear 2pop i; $28 $08 ifill
: ignore 2push 8clear 2pop i; $00 interrupt
: 0div $7FFFFFFF 1ld i;

\ Block 171
\
\ : idt -a ( table of 2-word interrupts. Edit convenient block number )
\ : 1ld n ( load register 1 with literal )
\ : lidt ( load interrupt descriptor table from byte address on stack )
\ : 2push ( save registers 0 and 2 )
\ : 2pop ( restore 2 and 0 )
\ : forth: ( save registers used by Forth )
\ : ;forth ( restore registers used by Forth )
\ : clear ( store 20 to port 20 to clear irq 0-7 )
\ : 8clear ( also 20 to port a0 to clear irq 8-f )
\ : i; ( return from interrupt - restore flags )
\ : lidt b ( execute lidt )
\ : interrupt n ( construct interrupt to ) here. ( Avoid yellow-green literal with red comment )
\ : ifill an ( n entries in default interrupt table )
\ : ignore ( clear ) ( grey = $01644001 ) ( interrupt. Doesnt clear the device )
\ : 0div ( make divisor +infinity, quotient 0 )

\ Block 172
( Admtek Comet An983b ) macro
: align here #7 and #3 xor drop if nop align ; then ; forth
: array pop 2/ 2/ ;
: us ( n ) khz @ #1000 #3 * / * for next ;
: r ( n-a ) $DB000000 + 2/ 2/ ;
: rom ( a-n ) $A4 + r @ ;
: 3rom ( nnn ) #4 rom #0 rom dup #16 for 2/ next swap ;
: reset #1 $00 r ! #1000 us ;
: frag #0 , $02000000 , $00 , here #4 + , ;
: tx align array frag frag frag frag frag frag
: n tx #1 + ;
: a tx #2 + ; #16 MagentaV f
: fr! f @ + ! ;
: first ( an ) #0 f ! $20000000 or
: send ( an ) $01000000 or n fr! a fr! $80000000 tx fr! #4 f + ! ;
: last ( an ) $42000000 or send #1 us
: poll #-1 $08 r ! ;

\ Block 173
\
\ : array -a ( returns word-aligned address in dictionary )
\ : us n ( delay n microseconds. Edit cpu clock rate )
\ : r n-a ( word address of register. Edit base address from ) north ( PCI device configuration )
\ : rom a-n ( fetch 2 bytes of ethernet id )
\ : 3rom -nnn ( 3 byte-pairs of id. )

```

```

\ : reset ( controller )
\ : tx -a ( transmit descriptor ring )
\ : n -a ( fragment length/control )
\ : a -a ( fragment address )
\ : send an ( fragment into descriptor queue )
\ : first an ( fragment. )
\ : last an ( fragment. Start transmission )

\ Block 174
( Receive ) #281880 MagentaV rxp
: rx align array $80000000 , $01000600 , $2000 block #4 * dup , here #4 + , $80000000 , $01000600 , $0600 + , rx #4 * ,
: init reset rx #2 * 2* $18 r ( receive ) ! #1 us tx #2 * 2* $20 r ( transmit ) ! #1 us $00202002 ( start ) $30 r ! #1 us
$00010040 $38 r ! sti #-1 $28 r ! ;
: link #3 + @ 2/ 2/ ;
: own? @ #0 or drop ;
: /int rpx @ $80000000 over ! link own? -if #-1 $28 r ! then ;
: rcvd rx nop
: wait dup own? -if link wait ; then dup rpx ! #2 + @ ;
: reg dup r @ h. space #2 h.n cr ;
: regs $B8 reg $A0 reg $98 reg $94 reg $78 reg $60 reg $48 #10 for dup reg #-8 + next drop ;
: ok show $00400000 rgb color screen text regs keypad ;
: rx1 $2000 block dump ;
: rx2 $2000 block $0180 + dump ; ok

\ Block 175
\
\ : rx -b ( receive descriptor ring )
\ : init ( ialize controller. Set tx/rx address/on and perfect match )
\ : link a-b ( next link in descriptor ring )
\ : own? a ( is this descriptor owned? )
\ : /int ( give up ownership of received packet , clear interrupt if no packet remains )
\ : rcvd -a ( return address of recieved packet )
\ : wait -b ( till packet received )
\ : reg a ( display register and address )
\ : regs ( display interesting registers )
\ : ok ( diagnostic display )

\ Block 176
( App: Ethernet ) empty
( interrupts ) #170 load
( hardware interface ) #172 load #174 load macro
: w $66 1, ;
: w@ $8B 2, ;
: w! $0289 2, drop ;
: *byte $C486 2, ; forth
: n@ w w@ $FFFF and *byte ;
: 2! a! w w! ;
: n! a! *byte w w! ;
: n, *byte 2, ;
: string pop ;
: packet string #-1 dup , 2, 3rom 2, 2, 2, #0 n,
: length ( n ) packet #12 + n! ;
: broadcast #-1 dup dup packet nop
: 3! swap over 2! #2 + swap over 2! #2 + 2! ;
: ethernet ( n ) length packet #14 first ;
: +ethernet ( -a ) rcvd #14 + ; fixthis
#2 #16 +thru breakhere ( todo fix this )
$2A interrupt
: serve forth: receive /int 8clear ;forth i; init ok discover

\ Block 177
\
\ : empty ( redefined to disable interrupts )
\ : w ( 16-bit prefix )
\ : w@ b-n ( fetch 16-bits from byte address )
\ : w! nb ( store 16-bits )
\ : *byte n-n ( swap bytes 0 and 1 )
\ : n@ b-n ( fetch 16-bit network-ordered number )
\ : 2! nb ( store 16-bit number )
\ : n! nb ( store 16-bit number in network order )
\ : n, n ( compile 16-bit number in network order )

```

```

\ : string -b ( returns byte address )
\ : packet -b ( ethernet packet header )
\ : dest -b ( destination field in packet )
\ : src -b ( source field )
\ : length n ( store length into packet )
\ : 3! nnnb ( store 3-word MAC )
\ : ethernet n ( send header with type/length )
\ : @ethernet -b ( return payload address of received packet )

\ Block 178
( ARP for a single correspondent ) macro
: move ( sdn ) $C189 2, drop $00C78957 3, drop $00C68956 3, $A4F3 2, $5F5E 2, drop ; forth
: . ( n ) 1, ;
: message string $01 n, $0800 n, $06 . $04 . $01 n,
: me 3rom 2, 2, 2, ( IP ) #0 . #0 . #0 . #0 .
: to #0 #0 #0 2, 2, 2, ( IP ) #0 . #0 . #0 . #0 .
: sender #8 + ;
: target #18 + ;
: dir #6 + ;
: ip #6 + w@ ;
: ar ( n ) message dir n! $0806 ( ARP ) ethernet message #28 last ;
: arp cli broadcast #1 ar sti ;
: -arp ( b-b ) dup #-2 + n@ $0806 or drop if ; then pop drop
: me? dup target ip message sender ip or drop if ; then dup sender packet #6 move
: query? dup dir n@ #1 or drop if ; then sender message target #10 move #2 ar ;

\ Block 179
\ ( Set ip addresses with Edit. Normal order, net bytes first )
\ : move sdn ( move n bytes from source to destination. Register 1 is used, 6 and 7 are saved )
\ : . n ( compile byte. Resembles URL punctuation )
\ : message -b ( 28-byte string )
\ : me ( comment marking my mac/ip address )
\ : to ( comment marking correspondent )
\ : sender
\ : target
\ : dir -b ( fields in either ) message ( or received message )
\ : ip b-n ( fetch ip address )
\ : ar n ( send query 1, or reply 2 )
\ : arp ( broadcast query )
\ : -arp b-b ( return if not ARP. Otherwise process and skip out. )
\ : me? b ( return if broadcast not for me. Save sender only in packet )
\ : query? b ( if a request, reply )

\ Block 180
( ipv4 )
: header align string $4500 n, #0 n, #1 n, #0 n, $FF11 n, #0 n, #0 , #0 ,
: length ( n ) header #2 + n! ;
: +id header #4 + dup n@ #1 + swap n! ;
: -sum for dup n@ u+ #2 + next drop dup $00010000 / + invert ;
: sum header #10 + n! ;
: checksum 0 sum #0 header #10 -sum sum ;
: source header #12 + ;
: destination header #16 + ;
: ip ( n-n ) dup #20 + $0800 ethernet length +id checksum header #20 send ;
: +ip dup #-2 + n@ $0800 or drop if pop ; then #20 + ;

\ Block 181
\ ( Set ip addresses with Edit. Normal order, net bytes first )
\ : header -a ( 40-byte ipv6 header )
\ : length n ( store 2-byte length in header )
\ : dest -a ( 4-byte destination ip address )
\ : src -a ( source ip )
\ : ip n ( send ip header embedded in ethernet packet )
\ : +ip b-b ( skip out if not IP. Otherwise return payload address )

\ Block 182
( UDP )
: xid 3rom + + ;
: b@ ( b-n ) w@ $FF and ;
: header string xid n, #0 n, #8 n, #0 n, #0 n,
: length ( n ) #8 + header #4 + n! ;

```

```

: port header #2 + n! ;
: from? over #8 + n@ or drop ;
: udp ( n ) dup #8 + ip length ;
: +udp ( b-b ) dup #11 + b@ #17 or drop if pop ; then #8 + ;

\ Block 183
\
\ : b@ b-n ( fetch byte )
\ : header -a ( 8-byte udp header )
\ : length n ( store length in header )
\ : port p ( set destination port )
\ : from? ap ( udp packet from port ) p ( ? )
\ : udp n ( send ip header for n-byte packet )
\ : +udp b-b ( skip out if not UDP. Otherwise return payload address )

\ Block 184
( DNS resolver ) $0CF42A44 MagentaV server #1671948608 MagentaV host
: msg string #0 , #1 n, #0 2, #0 , #1 n, #1 n,
: ptr? dup n@ $C000 and $C000 or drop ;
: skip ptr? if dup b@ if + #1 + skip ; then drop #1 + ; then #2 + ;
: length dup negate swap skip + ;
: 4! a! w! ;
: query server @ destination 4! #53 port dup length dup #16 + udp drop header #8 send msg #12 send send msg #12 + #4 last
;
: answer dup #12 + skip #4 + swap #6 + n@ ;
: resolve ( a-h ) #0 host ! query
: wait host @ #0 or if ; then drop wait ;
: rr+ #8 + dup n@ + #2 + ;
: -dns #53 from? if ; then pop drop answer
: rr #1 + -if #1 host ! ; then swap skip dup n@ #1 or drop if rr+ swap rr ; then
: address #10 + dup w@ host ! ;

\ Block 185
\ ( Assumptions )
\ : 1 ( a response contains one entry in the question section )
\ : 2 ( the first address in the answer section, if any, sufficiently resolves the query )
\ : server ( name server )
\ : host ( the resolved IP address )
\ : skip a-b ( skip past a domain field )
\ : length a-n ( length of a domain in bytes )
\ : query a- ( send DNS query to the DNS server )
\ : answer a-bn ( give the answer section and the number of resource records )
\ : resolve a-h ( resolve domain name to host address )
\ : wait -h ( wait for a response from the server )
\ : rr+ a-b ( skip a resource record )
\ : -dns ( dns packet recieved , search for address )
\ : rr a-b ( process resource record )
\ : address a-b ( set the host address )

\ Block 186
( Domain names ) #62 load macro
: 1! a! $0288 2, drop ;
: interp qdup $F889 2, ; forth
: word ch if 1, #1 u+ word ; then drop drop ;
: . here #0 1, interp #0 over @ #-16 and word #1 u+
: words over @ $0F ? if drop nip swap 1! ; then word #1 u+ words ;
: end #0 1, ;
: cf string . ( www ) . ( colorforth ) . ( com ) end
: google string . ( www ) . ( google ) . ( com ) end
: none string . ( none ) end

\ Block 187
\
\ : 1! xa- ( write byte at byte address )
\ : interp -a ( word address of next word to be interpreted )
\ : word w- ( compile packed word as ASCII characters )
\ : . ( compile counted ASCII string )
\ : words an- ( compile extensions words as ASCII )
\ : end ( of domain )
\ : none ( test of a non-existent domain )

```

```
\ Block 188
( DHCP client )
: fill for #0 , next ;
: msg align string $00060101 , xid , #5 fill 3rom 2, 2, 2, #0 2, #50 fill $6382 n, $5363 n, $00010135 3, $06030237 , #12
1, . ( colorforth ) $FF 2, #0 , $3204 n, #0 , $FF 1,
: eq over over or drop ;
: skip over #1 + b@ #2 + u+ ;
: find over b@ if eq if $FF or if drop skip find ; then then drop drop #2 + ; then drop #1 u+ find ;
: your #16 + w@ ;
: ack dup #6 find w@ server ! #3 find w@ message target #6 + 4! your dup source 4! message sender #6 + 4! #1 ar ;
: -dhcp #67 from? if ; then dup #4 + w@ xid or drop if ; then dup #240 + dup #53 find w@
: type #2 or if #7 or drop if ack then drop ; then drop
: offer #54 find w@ msg #261 + 4! your msg #267 + 4!
: request #272 $3604 $0103 msg #241 + n!
: bootp msg #259 + n! broadcast #-1 destination 4! #67 port udp header #8 send msg swap last ;
: discover #260 $FF00 bootp ;
```

```
\ Block 189
\
\ : xid -v ( a unique identifier used in all DHCP correspondence with this client )
\ : fill n ( fill ) n ( words )
\ : msg ( the DHCP message , both discover and request are contained , discover is ends at ) $FF 2,
\ : eq xy-xy ( test equality )
\ : skip at-bt ( skip DHCP option )
\ : find at-b ( find option of type ) t ( in option list )
\ : your a-h ( IP address )
\ : ack ao ( server acknowledge , assign your IP , router IP , and DNS server IP )
\ : -dhcp a ( receive DHCP packet with ) xid
\ : type aot ( receive offer ) 2 ( or ack ) 5
\ : offer ao ( received an offer , send a request )
\ : request ( request the offered parameters )
\ : bootp nt ( send a discover or request message )
\ : discover ( broadcast a discover message )
```

```
\ Block 190
( ICMP )
: header string $0800 n, $00 n, $00 ,
: icmp dup #-34 + b@ #1 or drop if ; then ;
: ping #8 ip header #8 last ;
```

```
\ Block 191
\ ( Client can get or put blocks to server )
\ : payload n-bn ( 2 bytes were appended to UDP header for block number )
\ : +put nn ( send block number. Append block as last fragment. Packet length distinguishes two messages )
\ : it b ( move 1024 bytes from packet to offset block )
\ : -got b-b ( if a 2-byte message, return. Otherwise move block to archive - 300+ - and skip out )
\ : receive ( check and decode received packet. ) +test ( returns if true, ) -test ( returns if false. Otherwise they ) pop
\ ( - skip-out - return from ) receive. ( Resulting stack need not be empty, since ) /forth ( will restore pre-interrupt
\ stack. ) pop ( must be in a word called by ) receive, ( it cant be nested )
\ : +get b ( send requested block from archive )
\ : get n ( send block number to request. Interrupt disabled lest reply interfer )
\ : put n ( send block )
\ : archive ( send blocks 0-161 - 9 cylinders ) icmp dhcp
```

```
\ Block 192
( Blocks to/from server )
: payload ( n-bn ) header #8 + n! header #10 ;
: +put ( nn ) #1026 udp over payload send + block 2* 2* #1024 last ;
: it ( b ) dup #2 + swap n@ #300 + block 2* 2* #1024 move ;
: -got ( b-b ) dup #-4 + n@ #2 #8 + or drop if it pop ; then ;
: receive +ethernet -arp +ip +udp -dns -dhcp -got
: +get ( b ) n@ #300 +put ;
: ... ( interrupt-protect words that transmit )
: get ( n ) cli #2 udp payload last sti ;
: put ( n ) cli #0 +put sti ;
: archive #161 for i put #1000 us -next ;
```

```
\ Block 193
\ ( Client can get or put blocks to server )
\ : payload n-bn ( 2 bytes were appended to UDP header for block number )
\ : +put nn ( send block number. Append block as last fragment. Packet length distinguishes two messages )
```

```

\ : it b ( move 1024 bytes from packet to offset block )
\ : -got b-b ( if a 2-byte message, return. Otherwise move block to archive - 300+ - and skip out )
\ : receive ( check and decode received packet. ) +test ( returns if true, ) -test ( returns if false. Otherwise they ) pop
\ ( - skip-out - return from ) receive. ( Resulting stack need not be empty, since ) /forth ( will restore pre-interrupt
\ stack. ) pop ( must be in a word called by ) receive, ( it cant be nested )
\ : +get b ( send requested block from archive )
\ : get n ( send block number to request. Interrupt disabled lest reply interfer )
\ : put n ( send block )
\ : archive ( send blocks 0-161 - 9 cylinders ) icmp dhcp

\ Block 194
( Format floppy ) empty forth #1 MagentaV hd
: array pop 2/ 2/ ;
: com align array $1202004D , $6C 2,
: done $03F4 a! p@ $D0 or drop if done ; then ;
: byte ( n ) ready p! ;
: sectors ( nn-n ) #18 for over byte hd @ byte dup #18 mod #1 + byte #2 byte #1 + next drop ;
: head ( nn-n ) dup hd ! $0400 * $1202004D + com ! seek com #6 command dup 2* - #1801 + sectors done ;
: cylinders ( n ) #0 swap for #0 head #1 head #1 + next stop drop ;
: format #12 cylinders ;

\ Block 195
\ ( Increase speed from 2 cylinders/s to 3 )
\ : array -a ( return next word address )
\ : com -a ( address of command string )
\ : done ( wait till last sector formatted. Till ready to read )
\ : byte n ( send byte to fdc when ready )
\ : sectors nn-n ( send 4 format bytes to each of 18 sectors. Sector number from 1 to 18 )
\ : head nn-n ( set head number. Issue seek and format commands. Starting sector number depends on cylinder, allowing 2 sector
\ times to step heads. Cylinder 1: 17 18 1 2 ... 16. 1801 + adjusts for 1s complement and for unsigned mod )
\ : cylinders n ( format both heads of each cylinder, starting at 0 )
\ : format ( standard number of cylinders. Smaller is faster )

\ Block 196
( Hard disk ) empty macro ( use this at your own ) risk
: 2/s ?lit $F8C1 2, 1, ;
: p!+ $42EE 2, ;
: 1! $91 1, drop ;
: insw 1! $97 1, $006DF266 3, $97 1, ;
: outsw 1! $96 1, $006FF266 3, $96 1, ; forth
: 2dup over over ;
: bsy $01F7 p@ $80 and drop if bsy ; then ;
: rdy ( -n ) $01F7 p@ #8 and drop if $01F0 a! #256 ; then rdy ;
: sector $01F3 a! swap p!+ #8 2/s p!+ #8 2/s p!+ #8 2/s $E0 or p!+ drop p!+ drop 2* 2* ;
: read ( an ) $20 sector #256 for rdy insw next drop ;
: write ( an ) bsy $30 sector #256 for rdy outsw next drop ; nload

\ Block 198
( boot: 3f fat0: 5f fat1: 25a5 dir: 2 cl forth: 8e6d cl )
: reg dup p@ $FF and #2 h.n space #3 h.n cr ;
: regs #7 for i $01F0 + reg -next ;
: ok show blue screen text regs keyboard ;
: cl $20 * $4AAB + ;
: buffer $2000 block ;
: ?fort dup @ $54524F46 or drop ;
: cl0 dup #5 + @ $00010000 * swap #6 + @ #16 2/s $FFFF and or ;
: find ( -n ) buffer dup #2 cl read #256 for ?fort if #8 + *next drop ; then cl0 pop drop ;
: fort $8E6D cl ;
: +2 $8000 u+ $0100 + ;
: reads for 2dup read +2 next drop drop ;
: writes for 2dup write +2 next drop drop ;
: get buffer fort #9 reads ;
: cf! #0 fort #2 writes ;

\ Block 200
( Deskjet ) empty #2 +load
: nb #768 #3 * ; #4 +load
: pixels for pix next drop drop ;
: drow string $33622A1B , $622A1B4D , $5730 2,
: rpt drow #10 type drop ;
: columns for $0264 #2 wipes dup buffer #8 * #768 pixels line rpt rpt #2 + next drop ;

```

```

: res #300 2, #300 2, #2 2, ;
: esci string $306C261B , $6F2A1B4C , $1B4D312E , $3033742A , $2A1B5230 , $55342D72 , ( 32672a1b 4025736 res res res res
) $32722A1B , $53343033 , $30722A1B , $722A1B41 , $000C4362 3,
: print esci #37 type $F0000000 #767 #1024 * #2 * + #1024 columns #6 type drop ;
: tx string $3F and if $3F or if ; then $C0 or ; then ;
: text tx map ! print ;
: it table map ! print ;

```

```

\ Block 202
( Printer ) macro
: p@ $EC 1, ;
: p! $EE 1, ;
: @w $8B66 3, ;
: @b $8A 2, ;
: +a $C2FF 2, ;
: bts $0010AB0F 3, drop ;
: 2/s ?lit $F8C1 2, 1, ; forth
: ready p@ $80 and if ; then ready ;
: delay for next ;
: emit $0378 a! p! +a ready +a $8D or p! #30 delay #1 or p! drop ;
: type for dup @b emit #1 + next ;
: buffer $0264 block #4 * ;
: string pop ;
: !b dup - #7 and a! dup #3 2/s bts #1 + ;
: three !b
: two !b
: one !b
: nul drop ;
: white $FFFF and dup $FFFF or drop if - then ;

```

```

\ Block 204
( Deskjet )
: -nb nb negate u+ ;
: bcmy string $10243800 , $3033 , $00200022 , $10000011 , $C00F , $4003 , $00 , $00 , $0008000A , $00 , $00800002 , $00 ,
$04000005 , $00 , $00 , $C0000001 ,
: ye nb #3 * u+
: all over over #3 and jump nul one two three
: ma -nb #2 2/s all ;
: cy -nb #2 2/s all ;
: bl -nb #2 2/s all ; #1050918 MagentaV map
: 6b $C618 and #3 2/s dup #3 2/s or $03C3 and dup #4 2/s or $3F and ;
: table string bcmy + @b ;
: ex map @ push ;
: pix over @w 6b ex $FF and if ye ma cy bl then drop #3 + #1024 #-2 * u+ ;
: arow string $30622A1B , $4D 1,
: trbp string $32622A1B , $00563838 3,
: trbr string $32622A1B , $00573838 3,
: color #7 type drop nb #8 / type ;
: line arow #5 type drop buffer #3 for trbp color next trbr color drop ;

```

```

\ Block 206
( x18 simulator ) empty macro
: 2/s ?lit $F8C1 2, 1, ; forth
: state $1FFF block ; nload
: reset r #26 for $00100000 over ! #1 + next drop $0180 mem @ ! r ! $0181 pc ! $00 slot ! ;
: un. #5 for #37 emit next ;
: undef $00100000 ? if drop un. ; then #5 h.n ;
: r. ( a-a ) dup @ undef cr #1 + ;
: stack sp @ $08 for dup ss r. drop #-1 + next drop ;
: return rp @ #8 for #1 + dup rs r. drop next drop ;
: ok show black screen text green return r r. blue r. r. white r. r. green r. r. drop stack keyboard ; reset ok

```

```

\ Block 207
\
\ : 2/s n ( shift right n bits )
\ : state -a ( address of state vector for current computer )
\ : reset ( set registers undefined, execute from ROM )
\ : un. ( display undefined register )
\ : h.n nn ( display n hex digits of number )
\ : undef n ( bit 20 set means undefined )
\ : r. ( display register )

```

```
\ : stack ( display stack, top at top )
\ : return ( display return stack, top at bottom )
\ : ok ( display registers, b a blue, pc ir white )
```

```
\ Block 208
```

```
( Registers )
```

```
: r state ;
: b state #1 + ;
: ar state #2 + ;
: pc state #3 + ;
: ir state #4 + ;
: t state #5 + ;
: s state #6 + ;
: slot state #7 + ;
: ss #7 and #8 + state + ;
: rs #7 and #16 + state + ;
: rp state #24 + ;
: sp state #25 + ;
: mem $2000 block + ; #4 +load #2 +load
: s1 ir @ #8 2/s inst ;
: s2 ir @ #3 2/s inst ;
: s3 #0 slot ! ir @ #4 and drop if ret then pc @ mem @ ir ! #1 pc +!
: s0 ir @ #13 2/s inst ;
: step slot @ jump s0 s1 s2 s3
: steps for step next ;
```

```
\ Block 209
```

```
\ ( Name 26 registers in state vector )
```

```
\ : ar -a ( A register. Cannot be named a because Pentium macro takes precedence )
```

```
\ : s0-s3 ( execute instruction from slot 0-3 )
```

```
\ : step ( execute next instruction )
```

```
\ : steps n ( execute n instructions )
```

```
\ Block 210
```

```
( Instructions )
```

```
: nul ;
: call pc @ +r
: jmp ir @ $01FF and pc ! ;
: jz t @ dup or
: jc drop if #3 slot ! ; then jmp ;
: jns t @ $00020000 and jc ;
: ret -r pc ! ;
: @b b @
: @x mem @ +t ;
: @+ ar @ #1 ar +! @x ;
: n pc @ #1 pc +! @x ;
: @a ar @ @x ;
: !b b @ #1 b +!
: !x -t swap mem ! ;
: !+ ar @ #1 ar +! !x ;
: !a ar @ !x ;
: inst ( n ) #1 slot +! $1F and jump jmp jmp call call jz jns jns @b @+ n @a !b !+ nul !a -x 2*x 2/x +* orx andx nul +x
r@ a@ t@ s@ r! alx nul !
```

```
\ Block 211
```

```
\ ( Define action of each instruction )
```

```
\ : inst n ( jump vector for 32 instruction codes )
```

```
\ Block 212
```

```
( Instructions )
```

```
: +r ( n ) r @ rp @ #1 + dup rp ! rs ! r ! ;
: -r ( -n ) r @ rp @ dup rs @ r ! #1 + rp ! ;
: +t ( n ) t @ s @ sp @ #1 + dup sp ! ss ! s ! t ! ;
: -t ( -n ) t @ s @ t ! sp @ dup ss @ s ! #1 + sp ! ;
: -x t @ $0003FFFF or t ! ;
: 2*x t @ 2* $0003FFFF and t ! ;
: 2/x t @ dup $00020000 and 2* or 2/ t ! ;
: +* t @ #1 ? if s @ + then 2/ t ! ;
: orx -t t @ or t ! ;
: andx -t t @ and t ! ;
: +x -t t @ + $0003FFFF and t ! ;
```



```

: r@ -r +t ;
: a@ ar @ +t ;
: t@ t @ +t ;
: s@ s @ +t ;
: r! -t +r ;
: alx -t ar ! ;
: t! -t drop ;

\ Block 213
\
\ : +r n ( push onto return stack )
\ : -r -n ( pop from return stack )
\ : +t n ( push onto data stack )
\ : -t -n ( pop from data stack )
\ : -x ( some instructions named with terminal x to avoid Pentium conflict )

\ Block 214
( x18 target compiler ) empt #2097556 MagentaV h #2097555 MagentaV ip #2 MagentaV slot macro
: 2*s ?lit $E0C1 2, 1, ; forth
: memory $2000 block ;
: org ( n ) memory + dup h ! ip ! #0 slot ! ;
: , ( n ) h @ ! #1 h +! ;
: s3
: s0 h @ ip ! #13 2*s , #1 slot ! ;
: s1 #8 2*s
: sn ip @ +! #1 slot +! ;
: s2 #3 2*s sn ;
: i, slot @ jump s0 s1 s2 s3
: 25x #174 load ; #8 +load #2 +load #4 +load n x18 call class 25x

\ Block 215
\ ( Prototype for target compilers )
\ : h ( address of next available word in target memory )
\ : ip ( address of current instruction word )
\ : slot ( next available instruction slot )
\ : 2*s n ( shift left n bits )
\ : memory -a ( host address for target memory )
\ : org n ( set current target memory location )
\ : , n ( compile word into target memory )
\ : s0-s3 ( assemble instruction into slot 0-3 )
\ : i, ( assemble instruction into next slot )
\ : 25x ( compile code for multicomputer )

\ Block 216
( Instructions )
: nop $1E i, ;
: adr ( n-a ) slot @ #2 or drop if nop then i, ip @ ;
: call defer ( a ) #2 adr +! ;
: if ( -a ) #4 adr ;
: -if ( -a ) #6 adr ;
: then ( a ) h @ $01FF and swap +! ;
: @+ $08 i, ;
: @b $09 i, ;
: n defer #8 f@ execute $0A i, , ;
: @ $0B i, ;
: !+ $0C i, ;
: !b $0D i, ;
: ! $0F i, ;
: - $10 i, ;
: 2* $11 i, ;
: 2/ $12 i, ;
: +* $13 i, ;
: or $14 i, ;
: and $15 i, ;
: + $17 i, ;

\ Block 217
\ ( Words being redefined for the target computer. These Pentium words can no longer be executed. Although Pentium macros
\ still take precedence during compilation, they will no longer be used. )
\ : adr n-a ( assembles instruction, but not in slot 2, where address goes. Instruction address left on stack )
\ : call ( deferred to class. Executed for target defined words )

```

```

\ : then a ( puts address in low 9 bits of previous instruction word )
\ : n ( executed for green short-numbers. All 18-bit target numbers are short. Executes white short-number to put interp
\ reted number on stack. Then assembles literal instruction with number in next location )

\ Block 218
( Instructions )
: pop $18 i, ;
: a $19 i, ;
: dup $1A i, ;
: over $1B i, ;
: push $1C i, ;
: a! $1D i, ;
: drop $1F i, ;
: ; #4 ip +! ;

\ Block 219
\ ( More target instructions )
\ : ; ( since it will be executed, it does not conflict with the Pentium macro )

\ Block 220
( 25x ROM ) $0180 org $00 dup - dup - dup - dup - dup - dup - dup - dup - dup push push push push push push push push push
a! a nop

\ Block 222
( Target )
: defer ( -a ) pop ;
: execute ( a ) push ;
: class ( a ) last #1 + ! ;
: fl! ( an ) sp + ! ;
: f@ ( n-a ) sp + @ ; #1445 MagentaV ?com #1369 MagentaV csho
: empty empt #0 class csho @ ?com @
: functions ( aa ) #4 fl! #6 fl! ;
: x18 ( a ) #4 f@ ?com ! #6 f@ csho ! #1 f@ functions ;

\ Block 224

\ Block 225
\

\ Block 226
( Realtek rtl8139b ) macro
: move ( sdn ) $C189 2, drop $00C78957 3, drop $00C68956 3, $A4F3 2, $5F5E 2, drop ; forth
: 1us #1
: us ( n ) #550 #3 / * for next ;
: r ( n-a ) $02000000 device $14 + pci + 2/ 2/ ;
: rom ( a-n ) r @ ;
: 3rom ( nnn ) #4 rom #0 rom dup #16 for 2/ next swap ;
: tx ( -b ) $2000 block #4 * ;
: rx ( -b ) tx #1536 + ; #1 MagentaV ds #42 MagentaV fr
: n ( -a ) ds @ $10 r + ;
: send ( an ) fr @ tx + swap dup fr +! move ;
: first ( an ) n @ $2000 and drop if ds dup @ #1 + #3 and swap ! #0 fr ! send ; then first ;
: last ( an ) send tx ds @ $20 r + ! fr @ #60 max n ! ;
: reset $10000000 $34 r ! #100 us ;
: init rx $30 r ! 1us reset $0C000000 $34 r ! 1us $8A $44 r ! #3 ds ! $FB dup $21 p! $A1 p! sti
: /int $FFFF0001 $3C r ! ;
: rcvd ( -b ) $38 r @ dup $00010000 / $1FFF and $FFFFFFF0 + $38 r ! $10 + $1FFF and rx #4 + + ;

\ Block 227
\
\ : move sdn ( move n bytes from source to destination. Register 1 is used, 6 and 7 are saved )
\ : us n ( delay n microseconds. Edit cpu clock rate )
\ : r n-a ( word address of register )
\ : rom a-n ( fetch 2 bytes of mac )
\ : 3rom nnn ( 3 byte-pairs of mac )
\ : tx -a ( transmit buffer. 1536 bytes. Fragments must be assembled for transmission )
\ : rx -b ( receive buffer. 8k + 1532 byte overrun )
\ : ds -a ( must cycle thru 4 tx descriptors )
\ : fr -a ( must accumulate fragments in tx buffer )
\ : n -a ( tx status/length. Writing starts transmission )

```

```

\ : send an ( fragment into transmit buffer )
\ : first an ( fragment. Wait till buffer empty )
\ : last an ( fragment. Start transmission )
\ : reset ( controller )
\ : init ( ialize controller. Set tx/rx address/on and mac/broadcast. Enable irq10 )
\ : rcvd -b ( received packet. Register 38 is 10 bytes before start of next packet. Register 3a is end of current packet
\ )

```

```

\ Block 228
( Display registers )
: reg ( a ) dup r @ h. space #2 h.n cr ;
: regs $48 #19 for dup reg #-4 + next drop ;
: ok show red screen text regs keyboard ;

```

```

\ Block 229
\
\ : reg a ( display register and address )
\ : regs ( display interesting registers )
\ : ok ( diagnostic display )
\ : 48 ( counter. Neat! )
\ : 44 ( rx configuration )
\ : 40 ( tx configuration )
\ : 3c ( interrupt )
\ : 38 ( rx count/address )
\ : 34 ( command )
\ : 30 ( rx 8k ring buffer )
\ : 2c-20 ( tx address )
\ : 1c-10 ( tx status )
\ : c-8 ( multicast id, unused )
\ : 4 ( mac 54 )
\ : 0 ( mac 3210 )

```

```

\ Block 230
( Ethernet ) empty #124 load
: empty empt logo cli ; macro
: w $66 1, ;
: w@ $8B 2, ;
: w! w $0289 2, drop ;
: *byte $C486 2, ; forth #126 load #128 load
: n@ w w@ $FFFF and *byte ;
: 2! a! w! ;
: n! a! *byte w! ;
: n, *byte 2, ;
: string pop ;
: packet string #-1 dup dup 2, 2, 2, 3rom 2, 2, 2, #0 n,
: length ( n ) packet #12 + n! ;
: 3! swap over 2! #2 + swap over 2! #2 + 2! ;
: ethernet ( n ) length packet #14 first ;
: +ethernet ( -a ) rcvd #14 + ; #132 load #134 load #136 load #138 load $72 interrupt
: serve forth receive /int 8clear /forth i; init ok

```

```

\ Block 231
\
\ : empty ( redefined to disable interrupts )
\ : w ( 16-bit prefix )
\ : w@ b-n ( fetch 16-bits from byte address )
\ : w! nb ( store 16-bits )
\ : *byte n-n ( swap bytes 0 and 1 )
\ : n@ b-n ( fetch 16-bit network-ordered number )
\ : 2! nb ( store 16-bit number )
\ : n! nb ( store 16-bit number in network order )
\ : n, n ( compile 16-bit number in network order )
\ : string -b ( returns byte address )
\ : packet -b ( ethernet packet header )
\ : dest -b ( destination field in packet )
\ : src -b ( source field )
\ : length n ( store length into packet )
\ : 3! nnnb ( store 3-word MAC )
\ : ethernet n ( send header with type/length )
\ : @ethernet -b ( return payload address of received packet )

```

```

\ Block 232
( ARP for a single correspondent )
: . ( n ) 1, ;
: message string $01 n, $0800 n, $06 . $04 . $01 n,
: me 3rom 2, 2, 2, ( IP ) #0 . #0 . #0 . #2 .
: to #0 #0 2, 2, 2, ( IP ) #0 . #0 . #0 . #1 .
: sender #8 + ;
: target #18 + ;
: dir #6 + ;
: ip #6 + w@ ;
: ar ( n ) message dir n! $0806 ethernet message #28 last ;
: arp cli #-1 dup dup packet 3! #1 ar sti ;
: -arp ( b-b ) dup #-2 + n@ $0806 or drop if ; then pop drop
: me? dup target ip message sender ip or drop if ; then dup sender packet #6 move
: query? dup dir n@ #1 or drop if ; then sender message target #10 move #4 ar ;

```

```

\ Block 233
\ ( Set ip addresses with Edit. Normal order, net bytes first )
\ : . n ( compile byte. Resembles URL punctuation )
\ : message -b ( 28-byte string )
\ : me ( comment marking my mac/ip address )
\ : to ( comment marking correspondent )
\ : sender
\ : target
\ : dir -b ( fields in either ) message ( or received message )
\ : ip b-n ( fetch ip address )
\ : ar n ( send query 1, or reply 4 )
\ : arp ( broadcast query )
\ : -arp b-b ( return if not ARP. Otherwise process and skip out. )
\ : me? b ( return if broadcast not for me. Save sender only in packet )
\ : query? b ( if a request, reply )

```

```

\ Block 234
( ipv6 )
: header string $01000060 , $00 n, $17 . #64 .
: to $00 , $00 , $00 , ( IP ) #0 . #0 . #0 . #2 .
: me $00 , $00 , $00 , ( IP ) #0 . #0 . #0 . #1 .
: length ( n ) header #4 + n! ;
: dest header #20 + ;
: src header #36 + ;
: ip ( n ) $86DD ethernet length header #40 send ;
: +ip ( b-b ) dup #-2 + n@ $86DD or drop if pop ; then #40 + ;

```

```

\ Block 235
\ ( Set ip addresses with Edit. Normal order, net bytes first )
\ : header -a ( 40-byte ipv6 header )
\ : length n ( store 2-byte length in header )
\ : dest -a ( 4-byte destination ip address )
\ : src -a ( source ip )
\ : ip n ( send ip header embedded in ethernet packet )
\ : +ip b-b ( skip out if not IP. Otherwise return payload address )

```

```

\ Block 236
( UDP )
: b@ ( b-n ) w@ $FF and ;
: header string #0 n, #0 n, #8 n, #0 n, #0 n,
: length ( n ) #8 + header #4 + n! ;
: udp ( n ) dup #8 + ip length ;
: +udp ( b-b ) dup #-34 + b@ $17 or drop if pop ; then #8 + ;

```

```

\ Block 237
\
\ : b@ b-n ( fetch byte )
\ : header -a ( 8-byte udp header )
\ : length n ( store length in header )
\ : udp n ( send ip header for n-byte packet )
\ : +udp b-b ( skip out if not UDP. Otherwise return payload address )

```

```

\ Block 238
( Blocks to/from server )
: payload ( n-bn ) header #8 + n! header #10 ;

```

```

: +put ( nn ) #1026 udp over payload send + block 2* 2* #1024 last ;
: it ( b ) dup #2 + swap n@ #300 + block 2* 2* #1024 move ;
: -got ( b-b ) dup #-4 + n@ #2 #8 + or drop if it pop ; then ;
: receive +ethernet -arp +ip +udp -got
: +get ( b ) n@ #300 +put ;
: ... ( interrupt-protect words that transmit )
: get ( n ) cli #2 udp payload last sti ;
: put ( n ) cli #0 +put sti ;
: archive #161 for i put #1000 us -next ; lblk @ edit

```

\ Block 239

```

\ ( Client can get or put blocks to server )
\ : payload n-bn ( 2 bytes were appended to UDP header for block number )
\ : +put nn ( send block number. Append block as last fragment. Packet length distinguishes two messages )
\ : it b ( move 1024 bytes from packet to offset block )
\ : -got b-b ( if a 2-byte message, return. Otherwise move block to archive - 300+ - and skip out )
\ : receive ( check and decode received packet. ) +test ( returns if true, ) -test ( returns if false. Otherwise they ) pop
\ ( - skip-out - return from ) receive. ( Resulting stack need not be empty, since ) /forth ( will restore pre-interrupt
\ stack. ) pop ( must be in a word called by ) receive, ( it cant be nested )
\ : +get b ( send requested block from archive )
\ : get n ( send block number to request. Interrupt disabled lest reply interfer )
\ : put n ( send block )
\ : archive ( send blocks 0-161 - 9 cylinders )

```

\ Block 240

```

( ipv4 )
: header align string $4500 n, #0 n, #1 n, #0 n, $FF00 n, #0 n, #0 ,
: length ( n ) #20 + header #2 + n! ;
: +id header #4 + dup n@ #1 + swap n! ;
: checksum ;
: source header #12 + ;
: destination header #16 + ;
: ip ( n-n ) dup #20 + $0800 ethernet length +id checksum header #20 send ;

```

\ Block 242

```

( Howerds test block ) empty macro
: gtend $7E 1, here invert + 1, ;
: init $B803F0BA , $EEEE0055 , ; forth
: h $01E5 ; ( h last class macros forths )
: allot ( n- ) h +! ;
: mk2 here $10 + ; $40 allot
: mk $01E2 ;
: class $01E9 ;
: macros $01EA ;
: forths $01EB ;
: mk macros @ mk2 ! forths @ mk2 #1 + ! h @ mk2 #2 + ! ;
: mt mk2 @ macros ! mk2 #1 + @ forths ! mk2 #2 + @ h ! ;
: reload #0 push ;
: qkey #3 for i next ; #57 MagentaV ky
: key pause $64 p@ #1 and drop if $60 p@ dup $3A - drop -if ky ! ; then drop then key ;
: kk key ky @ #57 - drop if kk then ;
: pt $03F0 ; here $04 / $12345678 , ,
: conf cli init $00 pt p! pt $01 + p@ $01 pt p! pt $01 + p@ ;

```

\ Block 243

```

\
\ : kk ( shows key values . press esc to exit )

```

\ Block 244

```

( IR remote ) empty macro
: 2/s ?lit $F8C1 2, 1, ;
: p@ $EC 1, ;
: p! $EE 1, drop ;
: 1@ $8A 2, ;
: 1! a! $0288 2, drop ; forth
: ba #10 /mod $011F a! p! $0118 + a! ;
: b@ ba #0 p@ ;
: b! ba p! ;
: us #748 * time + -
: till dup time + drop -if till ; then drop ;
: ms #1000 * us ;

```

```

: array pop #2 2/s ;
: nul ; #3 MagentaV onf #145 load #146 load #50 load #147 load #148 load #149 load #150 load #151 load #152 load #153 load
#155 load #154 load
: h keypd nul nul quit bye +db -db mute nul +xx -ch jp vcr tv0 dvd cd fm nul nul nul nul nul nul nul nul nul nul
$00152500 , $00091016 , $11001016 , $0E0A1002 , #0 , #0 , #0 ,

\ Block 245
\ ( smsc ircc2.0 IR Consumer mode ) $32 #10 b! #0 #12 b! #0 #20 b!
\ : buffer #200 block #4 * ;
\ : reset $10 #7 b! $80 #4 b! ;
\ : on $40 #5 b! ;
\ : off #2 #4 b! #200 ms ;
\ : emit #6 b@ $40 and drop if emit ; then #0 b! ;
\ : rdy #6 b@ $80 and drop ;
\ : get #0 b@ over 1! #1 + ;
\ : bytes for
\ : byte rdy if get dup buffer #4096 + or drop if byte ; then drop pop drop ; then next drop ;
\ : r #200 #1 wipes $80 dup #4 b! #5 b! buffer #1000000 bytes #0 #5 b! ;
\ : word - #4 for dup emit #8 2/s next drop ;
\ : cmd for word next #1
\ : sp for #0 word next ;
\ : rate #22 b! #21 b! ;
\ : sync $80 #20 b! ;

\ Block 246
( App: Slime : simple game ) empty ( sounds ) #4 +load
macro
: @w $8B66 3 , ; forth #2 MagentaV speed #13631840 MagentaV alice #29360784 MagentaV bob #0 MagentaV once #-1048576
MagentaV da
#-16 MagentaV db #17 MagentaV delay #25 MagentaV /del #-1 MagentaV off #0 MagentaV done
: mova da @ alice +! ;
: movb db @ bob +! ;
: qpel ( a- ) @ $00010000 /mod at vframe xy @ $00010000 /mod swap $0400 * + $02 * + @w $FFFF and #0 + if #1 done ! #1 off
! white bomb then ;
: clr #13 #65536 * #16 * #320 + alice ! #28 #65536 * #16 * #688 + bob ! #16 da ! #-16 db ! #0 delay ! #1 off ! #0 done !
#1 #1000 tn
: bgnd silver screen #16 #16 at black #1008 #672 box
: draw $FFFF color alice mova qpel #132 emit red bob movb qpel #133 emit ;
: tick off @ #0 + drop if ; then delay @ #-1 + delay ! -if /del @ delay ! draw click then ;
: b. ( c- ) $30 + 2emit ;
: ok show silver once @ #0 + drop if clr #0 once ! then silver #0 #708 at #600 #768 box #48 #708 at $00FFFF00 color #135
mute @ #0 + drop if #1 + then 2emit #0 emit speed @ #1 + b. tick keypad ; nload x ok h

\ Block 247
\ ( slime ) empt macro
\ : @w ( 16bit fetch )
\ : speed ( selected speed )
\ : alice ( 16:16 bit xy coordinate of left slug )
\ : bob ( 16:16 bit xy coordinate of right slug )
\ : once ( is set to initialise the game )
\ : mova ( move alice by the value in da )
\ : movb ( move bob by the value in db )
\ : delay ( counts the ticks for each move )
\ : /del ( the reset value for delay )
\ : qpel ( check for slime coloured pixel )
\ : clr ( set alice and bob to start positions )
\ : bgnd ( draw the background )
\ : draw ( the slugs )
\ : tick ( do this every screen update )
\ : ok ( the screen display )

\ Block 248
( Slime keypad )
: +speed #1
: +/-s speed @ + #0 max #9 min speed ! #10 speed @
invert + dup * #7 + #2 / #2 invert + /del ! ;
: -speed #-1 +/-s ;
: down #16 #65536 * da ! ; : up #-16 #65536 * da ! ;
: r #16 da ! ; : l #-16 da ! ;
: d2 #16 #65536 * db ! ; : u2 #-16 #65536 * db ! ;
: r2 #16 db ! ; : l2 #-16 db ! ;

```

```

: nul ;
: go #0 off ! ; : stop #-1 off ! ;
: x #1 once ! ;
: t off @ #0 + drop if #0 off ! ; then #-1 off ! ;
: help #249 edit ;
: mutet mute @ invert mute ! ;
: h keypad nul quit t nul nul nul nul l2 u2 d2 r2 x nul stop go nul nul nul l up down r -speed help mutet +speed $742E
, #0 , $13121110 , $31302078 , #0 , $13121110 , $2B6E682D ,

```

```

\ Block 249
\ ( Slime keypad )
\ : ludr ( move Alice and Bob left up down up )
\ : x ( reset the game )
\ : 0 ( stop the game )
\ : 1 ( start the game )
\ : - ( decrease the speed )
\ : h ( to see this help screen )
\ : m ( mute the sound - on/off )
\ : + ( increase the speed )
\ : . ( quit )
\ : t ( toggle on/off )
\ : slime: ( two players control Alice and Bob. The first to hit any slime or the edges loses. )
\ : credits: ( Coded by Howerd Oakford from an idea by Alan Crawley and Paul Chapman )
\ : tested: ( by Hannah Oakford )
\ : type slime ( to play again )

```

```

\ Block 250
( Sounds ) #20 MagentaV tempo #-1 MagentaV mute #90 MagentaV period
: tn ( ft- ) tempo @ * swap #660 #50 */
: hz ( tf- ) push #1000 #1193 pop */
: osc ( tp- ) dup period ! split $42 p! $42 p!
: tone ( t- ) mute @ #0 + drop if drop ; then $4F $61 p! ms $4D $61 p! #20 ms ;
: click #1 #90 osc ;
: t #3 tn ;
: q #8 tn ;
: c #16 tn ;
: 2tone #75 q #50 q ;
: h1 #50 c #54 q #50 q #45 c #60 c ;
: h2 #40 c #45 q #50 q #50 c #45 c ;
: h3 #54 c #60 q #54 q #50 c #45 q #40 q #50 t #45 t #50 t #45 t #45 #12 tn #40 q #40 #32 tn ;
: hh
: handel h1 h2 h3 ;
: piano #55 #7 for dup q #3 #2 */ next drop ;
: cetk #6 c #10 c #8 c #4 c #6 #32 tn ;
: bomb mute @ #0 + drop if ; then $4F $61 p! #500 for #1000 i invert + split $42 p! $42 p! #1 ms next $4D $61 p! #1 #32 tn
;

```

```

\ Block 251
\ ( Sounds )
\ : tempo ( in ms per 1/8 quaver )
\ : mute ( equals -1 to disable sound )
\ : period ( test only - value sent to hardware )
\ : tn ( ft- play f Hz for t * 11 ms )
\ : hz ( tf- play t ms at f Hz )
\ : osc ( tp- play t ms of period p )
\ : tone ( t- play the current tone for t ms )
\ : click ( makes a click )
\ : t ( triplet )
\ : q ( quaver )
\ : c ( crotchet )
\ : 2tone ( 2 tones )
\ : h1
\ : h2
\ : h3
\ : hh
\ : handel ( part of Handels Gavotte )
\ : piano
\ : cetk ( Close Encounters of the Third Kind )
\ : bomb ( - well sort of .... )

```

```

\ Block 252

```

```
( App: colorforth editor ) empty nload qinit
: eddd jblk @ ok h ( drop ) ;
: edd ( b- ) jblk @ jlast ! jblk ! eddd ; blk @ jblk ! #206 jlast ! eddd
```

```
\ Block 253
\ ( The colorforth editor in colorforth )
```

```
\ Block 254
( Editor circular buffers ) #0 MagentaV cbn #0 MagentaV ends
: data ( - ) cbn @ $01 invert and cbn ! ;
: ptrs ( - ) cbn @ $01 or cbn ! ;
: heads ( - ) cbn @ $02 invert and cbn ! ;
: tails ( - ) cbn @ $02 or cbn ! ;
: cb@ ( -c ) ends @ cbn @ #8 * rshift $FF and ;
: cb! ( c- ) $FF and cbn @ #8 * lshift ends @ $FF cbn @ #8 * lshift invert and or ends ! ;
: cbnum ( -n ) cbn @ heads cb@ tails cb@ - $FF and swap cbn ! ;
: cbuf ( -a ) r@ $0100 / #2 + cbn @ $01 and + block ;
: tl- ( -n ) cbnum ?f drop 0if $00 ; then tails cb@ cbuf + @ cb@ #1 + cb! ;
: tl+ ( -n ) tails cbnum $FF - drop 0if tl- drop then cb@ $01 - cb! cb@ cbuf + ! ;
: hd@ ( -n ) heads cb@ cbuf + @ ;
: hd- ( -n ) cbnum $00 - drop 0if $00 ; then hd@ cb@ #1 - cb! ;
: hd! ( -n ) heads cb@ cbuf + ! ;
: hd+ ( -n ) cbnum $FF - drop 0if tl- drop then heads cb@ $01 + cb! hd! ; #4 +load
```

```
\ Block 255
\
\ : cbn ( bit 0 selects one of two circular buffers. Bit 1 selects head or tail value )
\ : cb@
\ : cb! ( read/write a byte to one of the 4 in ends selected by cbn )
\ : ptrs ( selects the pointer buffer )
\ : data ( selects the data buffer )
\ : heads ( selects the head value )
\ : tails ( selects the tail value )
\ : cbnum ( gives the number of items in the currently selected buffer )
\ : cbuf ( returns the address of the start of both buffers - the next 2 blocks )
\ : tl+
\ : tl-
\ : hd+
\ : hd- ( add or subtract from the head or tail of the currently selected buffer )
\ : ... ( note the tl- in hd+ . if the buffer is full we remove the oldest from the tail )
```

```
\ Block 256
( r App:ay buffer string Undo Display r ir sr tr lr fr dr 0r or ; r rr rrr rt
r er rer rar mr rir ar rcr rlr rfr rdr nr r8r r;r tr trr ir tor te
r tar tnr sr tsr tcr tlr tfr cr t0r t8r t;r or lr otr oor oer oar f
r oir osr ocr olr dr odr o0r o8r o;r 0r err etr eor eer 8r enr eir es
r ecr ;r efr edr e0r e8r rr ar arr atr aor rrr aar anr air asr rtr al
r afr adr a0r aor a;r nr nrr ntr rer ner nar nnr nir rar ncr nlr nfr nd
r mnr n8r n;r ir irr rir ior ier iar inr rsr isr icr ilr ifr rcr i0r i8
r i;r sr rlr ser snr ssr slr rfr s8r mr mtr mer rdr msr mlr mdr m8r r0
r ctr cer cnr csr r8r cdr c8r yr ytr r;r ynr ysr ylr ydr tr lr ltr le
r lnr trr llr ldr l8r gr ttr ger gnr gsr glr tor g8r fr ftr fer ter fs
r flr fdr f8r tar wtr wer wnr wsr tnr wdr w8r dr dsr tir vsr pr psr b
r tsr hr hs r xr xsr tcr usr qsr 0r tlr 1r 1sr 2r 2sr tfr 3sr 4r 4s
r 5r tdr 6r 6sr 7r 7sr t0r 8sr 9r 9sr jr t8r -r -sr kr ksr t;r .sr z
r zsr ;r :r !s cccc cccc r !sr +r +sr @ bbbbr @r ot bbbbr *s )
```

```
\ Block 257
\
```

```
\ Block 258
( Display Undo string buffer ) #0 MagentaV jcur #64 MagentaV jblk
: sze ( -n ) $E0 ;
: qinit #0 ends ! $00 ptrs hd! $10000009 data hd! ;
: qnew ( - ) #0 ptrs hd+ ;
: qnum ( -c ) ptrs hd@ ;
: qpop ( -n ) data hd- ptrs hd@ #1 - if hd! ; then hd- drop drop ;
: qpush ( -n ) data hd+ ptrs hd@ $FF - drop 0if drop then ptrs hd@ #1 + hd! #0 #0 MagentaV pos #0 MagentaV lpos
: 2toc ( -a ) jblk @ block pos @ + + ;
: xtoc? ( -n ) #1 2toc @ $0F and ;
: rtocs ( - ) jcur @ pos !
```



```

: ntocs ( -n ) #0 2toc @ $0F and #12 - ?f drop 0if #2 ; then #1 xtoc? ?f drop 0if #1 + then $FF and ;
: ltocs ( -n ) #0 pos !
: ltcs pos @ jcur @ - drop -if pos @ lpos ! ntocs pos +! ltcs drop then jcur @ lpos @ - ;
: mx ( n- ) jcur @ + #0 max #255 min jcur ! ;
: ml ltocs negate mx ;
: mu #8 for ml next ;
: mr rtocs mx ;
: md #8 for mr next ; nload

```

\ Block 259

```

\
\ : qinit ( initialises the queue pointers )
\ : qnew ( starts a new string entry )
\ : qnum ( -c number of cells in the top string )
\ : qpop ( -n returns the top cell of the top string )
\ : qpsh ( n- stores n in the top string )
\ : ntocs ( number of tokens in the top string )
\ : qq ( n- ) qnew for qnum @ $0100 * $10000009 + qpsh next cbnum drop ;
\ : qq qinit #50 for #5 qq next #3 qq ;
\ : vv ptrs cbnum data cbnum ;
\ : kk c vv qpsh ptrs hd@ ;
\ : gg cbuf dump ;

```

\ Block 260

```

( Editor Display ) #0 MagentaV cblind
: cb cblind @ #0 + drop ; #16 MagentaV state $10 MagentaV state*
: yellow $00FFFF00 color ;
: +txt white $6D emit space ;
: -txt white $6E emit space ;
: +imm yellow $58 emit space ;
: -imm yellow $59 emit space ;
: +mvar yellow $09 emit $11 emit $05 emit $01 emit space ;
: txs string $03010100 , $07060504 , $09090901 , $0F0E0D0C , ( ; )
: tx ( c-c ) $0F and txs + 1 @ $0F and ;
: .new state @ $0F and jump nul +imm nul nul nul nul nul nul +txt nul nul +mvar nul nul nul ;
: .old state @ $0F and jump nul -imm nul nul nul nul nul nul -txt nul nul nul nul nul ;
: state! ( n- ) dup #0 + drop 0if drop ; then tx cb 0if drop ; then state @ swap dup state ! - drop if .old .new state @
#0 + if dup state* ! then drop then ; nload

```

\ Block 261

```

\
\ : state
\ : state! ( acts on a change of token type. It ignores extension tokens )

```

\ Block 262

```

( Editor Display ) macro
: @b $8A 2, ; forth #160 MagentaV jcmt #206 MagentaV jlast #2 MagentaV jcol
: bksp xy @ #22 $00010000 * negate + xy ! ;
: ?.cur jcmt @ #1 + #255 min jcmt ! jcur @ jcmt @ negate + #1 + drop 0if $00FF4040 color bksp $30 emit white then ;
: x xy @ $00010000 / ;
: ?cr x #1000 negate + drop -if ; then
: ncr xy @ #30 + $FFFF and $00030000 xor xy ! ;
: emt ?cr emit ;
: emit emt ;
: emitw unpack if emit emitw ; then space drop drop ;
: emitcs unpack if #48 + emit emitcs ; then space drop drop ;
: dig pop + @b $FF and emit ;
: edig dig $1B1A1918 , $1F1E1D1C , $13052120 , $0E04100A ,
: odig dup $0F and swap 2/ 2/ 2/ 2/ $0FFFFFFF and ; nload

```

\ Block 263

```

\
\ : ncr ( new cr -does not get confused with original )

```

\ Block 264

```

( CAPITALS HPO 2004 Editor Display )
: .hex odig if .hex edig ; then drop edig ;
: .dec #-1 ? -if negate #35 emit then
: n #10 /mod #-1 ? if .dec edig ; then drop edig ;
: num if $00C0C000 and color cb if #24 emit #21 emit then .hex space ; then color .dec space ;
: txt $00FFFFFF color emitw ;

```

```

: blu $FF color emitw ;
: cap $00FFFFFF color unpack #48 + emit emitw ; $00 MagentaV caps?
: caps $00FFFFFF color emitcs #-1 caps? ! ;
: ex bksp caps? @ ?f drop if caps ; then emitw ;
: gw $FF00 color emitw ;
: cw $FFFF color emitw ;
: yw $00FFFF00 color emitw ;
: coly #2 jcol ! ;
: colr #4 jcol ! ;
: colg #5 jcol ! ;
: colm #13 jcol ! ;
: colc #8 jcol ! ;
: colb #14 jcol ! ;
: rot $8B045E8B , $046E892E , $C38B0689 , $C3 1, #1220107268 MagentaV last nload

\ Block 265
\
\ : caps
\ : caps? ( is true if the extension token is CAPITALS )
\ : txt? ( returns true if the last token was text )
\ : .hex
\ : .dec

\ Block 266
( Editor display )
: short push dup 2/ 2/ 2/ 2/ swap $10 and drop pop num ;
: ys $00FFFF00 short ;
: long push #1 u+ $10 and drop dup @ pop num ;
: yn $00FFFF00 long ;
: gs $FF00 short ;
: gn $FF00 long ;
: var $00FF00FF color emitw #0 gn ;
: x xy @ $00010000 / ;
: rcr x #0 xor drop if cr then ;
: rw xy @ $FFFCFFFD + drop if rcr then $00FF0000 color cb if #41 emit space then emitw ;
: nulld drop ;
: .word ( w- ) dup #-16 and swap $0F and if $00 caps? ! then dup state! jump ex yw yn rw gw gn gs cw ys txt cap caps var
blu nulld nulld ( ; )
: t #0 jcnt ! jblk @ block text #3 lm #1024 rm #3 #3 at $10 state ! $10 state* !
: n dup @ #-1 ? if ?.cur .word #1 + n ; then drop drop $0F state! ; white #103 emit ;
: ok show $00200040 color screen t keypad ; nload

\ Block 267
\ ( CAPITALSALLTHEWAY! )

\ Block 268
( Editor aaaa bbbb cccc dddd keypad insertion )
: ripple ( a- ) dup dup @ over #1 + @ rot ! swap #1 + ! ;
: toc ( -a ) jblk @ block jcur @ + ;
: toend ( -n ) sze jcur @ - #0 max sze min ;
: del toc @ qpush toc toend for dup ripple #1 + next #0 swap ! drop ;
: dels jcur @ ?f drop 0if ; then ml qnew rtocs for del next ;
: ins ( n- ) sze jcur @ - ?f drop -if ; then jblk @ block sze + toend for #1 - dup ripple next ! ;
: undo qpop ins ;
: undos qnum ?f 0if drop ; then for undo next mr ; #25 MagentaV ky
: key pause $64 p@ #1 and drop if $60 p@ dup $3A - drop -if ky ! ; then drop then key ;
: lst ( n- ) jblk ! ok key drop ; nload

\ Block 269
\ ( Editor main keypad )
\ : ripple ( a- swaps the values at a and a+1 )
\ : bpush
\ : bpop ( push and pop the edit stack TBD )
\ : del ( removes the cell at the current cursor )
\ : dels ( removes the extension cells and one non extension coll before the cursor )
\ : undo ( puts back one cell )
\ : undos ( puts back one word which may have extension cells )

\ Block 270
( Editor keypad cursor )
: btog ( n-n ) dup #1 and drop if #1 invert and dup jblk ! ; then #1 xor dup jblk ! ;

```

```

: cbtog cblind @ invert cblind ! ;
: lastb ( n-n ) jlast @ dup jblk ! swap jlast ! ;
: blkld jblk @ $FFFFFFFE and #-32 + drop -if ; then jblk @ load ;
: -blk ( n-n ) #-2 + #18 max dup jblk ! ;
: +blk ( n-n ) #2 + #252 min dup jblk ! ;
: accep drop xx ;
: h keypd nul dels accep undos coly colr colg btog ml mu md mr -blk colm colc +blk colb nul nul nul cbtog nul nul lastb blkld
nul nul nul $00072515 , $2D0D010B , $0110160C , $2B0A0923 , $023A3800 , $03000029 , $3C ,

```

\ Block 272

```

( App: Conways Game of Life ) empty nload
: 1cell ( n-- ) #32 /mod adj adj over over at #16 u+
  #16 + box ;      : nocell ( n-- ) drop ;
: draw ( n-- ) dup old @ #1 and jump nocell 1cell
: allcls ( -- ) #1023 for i draw -next ;
: gen ( -- ) #1023 for i tick swap new ! -next #1023 for i new @ i old ! -next ;
: locn ( --n ) row @ #32 * col @ + ;
: cur ( -- ) locn dup old @ $FF * $00FF0000 + color 1cell ;
: back ( -- ) black screen $00303010 color #40 #40 at
  #583 dup box ;
: g ( -- ) show back green allcls gen keypad ;
: s ( -- ) gen show back blue allcls cur keypad ;
: clear ( -- ) #1500 #8 wipes #16 row ! #16 col ! s ;
: t ( -- ) locn old dup @ #1 xor swap ! ;
: col! ( n-- ) col +! col @ #31 and col ! ;
: l1 ( -- ) #-1 col! ; : r1 ( -- ) #1 col! ;
: row! ( n-- ) row +! row @ #31 and row ! ;
: up1 ( -- ) #-1 row! ; : dn1 ( -- ) #1 row! ;
: h keypd nul nul quit nul nul nul nul l1 up1 dn1 r1 nul nul nul nul glide glid2 glid3 glid4 clear s g t nul nul nul
rando $2E00 , #0 , $13121110 , #0 , $1C1B1A19 , $74677378 , $52000000 , clear glide g h

```

\ Block 273

```

\
\ : s ( stop )
\ : g ( go )
\ : t ( toggle the square )
\ : ludr ( left up down right )
\ ( press s to stop then draw a shape using ludr and t to toggle )
\ ( then press g to go or s to single step )
\ : 1234 ( create gliders which move to the four corners counting clockwise from the top left )
\ ( R loads random numbers )

```

\ Block 274

```

( Conways Game of Life ) #16 MagentaV row #16 MagentaV col
: old ( n-a ) cells #1500 block + ;
: new ( n-a ) cells #1504 block + ;
: rando ( -- ) #0 old $03FF for rand over ! cell+ next drop ;
: pos swap #32 /mod swap ;
: val #32 * + swap over old @ #1 and + ;
: up pos swap #31 + #31 and val ;
: dn pos swap #1 + #31 and val ;
: lt pos #31 + #31 and swap val ;
: rt pos #1 + #31 and swap val ;
: nul ;      : n2 #0 ;
: s2 dup old @ #1 and ; : y2 #1 ;
: tick dup #0 up lt dn dn rt rt up up nip jump n2 n2 s2 y2 n2 n2 n2 n2
: adj ( nn--nn ) swap #17 * #40 + ;
: st ( rc- ) col @ + swap row @ + #32 * + old #1 swap ! ;
: glide ( -- ) #0 $02 st #0 #1 st #0 #0 st #1 #0 st #2 #1 st ;
: glid2 #0 #0 st #0 #1 st #0 #2 st #1 #2 st #2 #1 st ;
: glid3 ( -- ) #0 #2 st #1 #2 st #2 #2 st #2 #1 st #1 #0 st ;
: glid4 ( -- ) #0 #0 st #1 #0 st #2 #0 st #2 #1 st #1 #2 st ;

```

\ Block 276

```

( Wave audio SB, 8 bit, mono, no DMA ) empt macro
: pb@ 0 $EC 1, ;
: pb! $EE 1, drop ;
: /8 $0008F8C1 3, ; forth
: +base $0220 + ; ( * )
: ?rd $0E +base a!
: *?rd pb@ $80 ? drop if ; then *?rd ;

```

```

: ?wr $0C +base a!
: *?wr pb@ $80 ? drop if *?wr then ;
: dsp@ ?rd $0A +base a! pb@ ;
: dsp! ?wr pb! ;
: ?init dsp@ $AA or drop if ?init ; then ;
: 0dsp #6 +base a! #1 pb! #30 for pb@ drop next #0 pb! ?init $D1 dsp! ; 0dsp
: *dac! $10 dsp! dup dsp! /8 ;
: dac! *dac! *dac! *dac! *dac! drop ;
: length #2 + dup #-1 + @ 2/ 2/ ;
: ?data dup @ $61746164 or drop if length + ?data ; then length ;
: sound #100 block #3 + ?data ; ( * )
: play for dup @ dac! #1 + next drop ;

\ Block 277
\
\ : pb@ ( -n get byte from port )
\ : pb! ( n- put byte to port )
\ : /8 ( n-n shift 8 bit right )
\ : +base ( n-n add base address )
\ : ?rd ( wait for DSP read ready )
\ : ?wr ( wait for DSP write ready )
\ : dsp@ ( -n read DSP )
\ : dsp! ( n- write DSP )
\ : ?init ( wait until initialized )
\ : 0dsp ( reset 3 us DSP, turn on speaker )
\ : dac! ( n- write 4 byte to DAC )
\ : length ( a-an return length of record )
\ : ?data ( a-an search data record )
\ : sound ( -an return address and length of sound data )
\ : play ( an- play sound )

\ Block 278
( App: colorforth Explorer ) empty #9 MagentaV strt
: ?size ( a- ) dup #510 block - drop ;
: crs ( n- ) ?f if for cr next #0 then drop ;
: docrs cr strt @ negate #0 max crs ;
: up1 ( a-a ) ?size +if ; then $0400 + dup @ $FFFFFFF0 and $5C58BC80 - drop 0if ; then up1 ;
: upn ( n-a ) #0 max #64 block up1 swap ?f if for up1 next ; then drop ;
: ln ( a- ) #4 for cell+ dup @ dup $0F and $01 - ?f drop
  0if drop leave then if dotsf then next drop ;
: .line ( a- ) ?size +if drop ; then cr dup ablk . ln ;
: lines ( -- ) strt @ #0 max upn #20 strt @ negate #0 max - ?f if for blue dup .line up1 next then drop ;

: marker iconh #11 * #4 - ;
: qok show $4228 color screen #240 #0 at blk block ln $00 color #0 marker at #1023 marker #30 + box #0 #0 at
docrs lines keypad ;
nload

\ Block 279
\ ( Scans the first cell of each block for App: )
\ ( and displays the first 4 words after App: )
\ : +
\ : - ( step through the applications )
\ : ? ( displays the applications first shadow block )
\ : o ( loads the application )
\ : . ( requires ) .word ( from the editor )
\ : up1 ( takes the address of the start block and steps through even blocks until it finds a token App: )

\ Block 280
( explorer )
: go strt @ #9 + upn ablk noshow ld ;
: md strt @ #1 - #-9 max strt ! ;
: mu strt @ #1 + #512 #4 / min strt ! ;
: qed strt @ #9 + upn ablk dup blk ! edit ;
: qh keypd nul quit go nul qed nul nul qed nul nul nul md nul nul mu nul nul nul nul nul nul nul nul nul
$002D2500 , $3F202065 , $00 , $2B20202D , $00 , $00 , $00 , qok qh

\ Block 281
\ ( Scans the first cell of each block for App: )
\ ( and displays the first 4 words after App: )
\ : +

```

```
\ : - ( step through the applications )
\ : ? ( displays the applications first shadow block )
\ : o ( loads the application )
\ : . ( requires ) .word ( from the editor )
\ : up1 ( takes the address of the start block and steps through even blocks until it finds a token App: )
```

```
\ Block 282
( fix the font )
: glyph ( c--a ) #48 * font @ + ;
: fix ( from to -- ) swap glyph swap glyph $30 cmove ;
: fixa $27 $3A fix $5B $01 fix $5C $02 fix $5D $03 fix
$20 $04 fix ;
: fixb $28 $5B fix $29 $5D fix ;
```

```
\ Block 283
\
```

```
\ Block 284
( grey = #-29727166 )oken ( test ) ( grey = #19138560 ) ( all tokens )
: tok ( t-n ) $11110000 + ;
: loc #2000 block ;
: set $10 for i #1 - tok loc i + ! next #9 tok loc ! #0 loc #17 + ! loc dump ; set
```

```
\ Block 288
( App: Timer Interrupt ) empty
( Interrupts ) #170 load
#0 MagentaV ticks
```

```
: !pit $34 $43 p! ( lo ) $A9 $40 p! ( hi ) $04 $40 p! ; !pit
: pic1! $21 p! ; : pic2! $A1 p! ;
: p@ p@ ; : p! p! ;
: ttb $20 p@ $21 p@ $A0 p@ $A1 p@ ;
: bpic cli ( init ) $11 dup $20 p! $A0 p!
( irq ) $00 pic1! $08 pic2! ( master ) #4 pic1! ( slave ) #2 pic2! ( 8086 mode ) #1 dup pic1! pic2! ( mask irq ) $8F pic2
! $B8 pic1! ;
: npic cli ( init ) $11 dup $20 p! $A0 p!
( irq ) $20 pic1! $28 pic2! ( master ) #4 pic1! ( slave ) #2 pic2! ( 8086 mode ) #1 dup pic1! pic2! ( mask irq ) $8F pic2
! $B8 pic1! ;
npic ( Note: npic will break bochs )
$20 interrupt
: timer0 forth: #1 ticks +! clear ;forth i;
( cli to disable interrupts , sti to enable )
sti
: test cli #0 ticks ! #1 secs sti #100 secs cli ;
: tm cli #0 ticks ! ;
lblk @ edit
( Type bye after loading in bochs !!!! )
```

```
\ Block 289
\ ( Timer Interrupt )
\ : !pit ( sets up the programable interval timer to )
\ ( 1 khz for a 1 ms tick )
\ ( for a clock of 14.31818 / 12 or 1.19318167 Mhz )
\ ( +/- 400 Hz this is actually 0.99985 +/- 0.0004 )
\ ( ms or about 0.015 percent fast. )
\ : pic1! ( write an octet to interrupt controller 1 )
\ : pic2! ( write an octet to interrupt controller 2 )
\ : !pic ( sets up the PIC chips )
\ $20 interrupt ( is the timer interrupt )
\ : timer0 ( the Forth code to run every timer tick )
\ ( use ) sti ( to enable interrupts, ) cli ( to disable )
\ : test ( run a 100 second test to time the timer )
<-- Unknown Blue token = 908FB00E crr+
\ ( interrupt with respect to the Real Time Clock. )
\ : tm ( measure cpu ms in timer ticks )
```

```
\ Block 290
( App: Sounds ) jmk #20 MagentaV tempo #0 MagentaV mute #1807 MagentaV period
: tn ( ft- ) tempo @ * swap #660 #50 */
: hz ( tf- ) push #1000 #1193 pop */
: osc ( tp- ) dup period ! split $42 p! $42 p!
```

```

: tone ( t- ) mute @ #0 + drop if drop ; then $4F $61 p! ms $4D $61 p! #20 ms ;
: click #1 #90 osc ;
: t #3 tn ;
: q #8 tn ;
: c #16 tn ;
: 2tone #75 q #50 q ;
: h1 #50 c #54 q #50 q #45 c #60 c ;
: h2 #40 c #45 q #50 q #50 c #45 c ;
: h3 #54 c #60 q #54 q #50 c #45 q #40 q #50 t #45 t #50 t #45 t #45 #12 tn #40 q #40 #32 tn ;
: hh
: handel h1 h2 h3 ;
: piano #55 #7 for dup q #3 #2 */ next drop ;
: cetk #6 c #10 c #8 c #4 c #6 #32 tn ;
: bomb mute @ #0 + drop if ; then $4F $61 p! #500 for #1000 i - + split $42 p! $42 p! #1 ms next $4D $61 p! #1 #32 tn ; 2tone
jmt

```

```

\ Block 292
( App: Test block : ) empty #-3 MagentaV strt #62976 MagentaV lstup
: size #256 block ;
: crs ( n- ) ?f if for cr next ; then drop ;
: up1 ( a-a ) dup size - drop +if ; then $0100 + dup @ $FFFFFFF0 and $5C58BC80 - drop 0if dup lstup ! ; then up1 then ;
: .line ( a- ) dup size - drop +if drop ; then cr dup $0100 / . #4 for #1 + dup @ dotsf next drop ;
: upn ( n-a ) ?f if #0 swap for up1 next ; then #0 ;
: lines strt @ negate #0 max crs strt @ #0 max upn #16 for up1 blue dup .line next drop drop ;
: ok show $00444444 color screen #240 #0 at r@ $0100 / block #4 for #1 + dup @ dotsf next drop $00 color #0 #266 at #1023
#296 box #0 #0 at lines keyboard ;
: go strt @ #9 + upn $0100 / ld xx ;
: md strt @ #1 - #8 max strt ! ;
: mu strt @ #1 + #256 min strt ! ;
: ?? strt @ #9 + upn $0100 / #1 + lst xx ;
: h keypd nul nul accept nul go nul nul ?? nul nul nul nul md nul nul mu nul nul nul nul nul nul nul nul nul
$00 , $2F000003 , $00 , $2B000023 , $00 , $00 , $00 , $00 , ok h

```

```

\ Block 293
\ ( saving and restoring the dictionary )
\ . ( allows just-in-time compilation )
\ . ( the code for ) 2tone ( only exists for as long as it is needed )

```

```

\ Block 294
( App: Serial terminal ) empty #52 load #48 load
#65 MagentaV char #0 MagentaV qchar #0 MagentaV pos
: - ( nn-n ) negate + ;
: 0eq ( n- ) ?f if #0 #0 + drop ; then #1 #0 + drop ;
: 1eq #0 + drop ;
: eq ( nn- ) - 0eq ;
: crr pos @ $1E + $FFFF and pos ! ;
: cls black screen #0 pos ! ;
: act qchar @ 0eq if ; then pos @ $00010000 /mod swap at blue char @ chc emit xy @ pos ! char @ #13 eq if crr then char @
#12 eq if cls then #0 qchar ! ;
: wait pause qchar @ 1eq if wait then ;
: ch ( c- ) rkey? if rkey $FF and char ! #-1 qchar ! then ;
: ok c cls act #0 pos ! show ch act $00 #650 at $00202020 color #1024 #768 box keyboard ;

```

```

\ Block 295
\ ( The next two blocks are a 256 character 8*8 pixel font )
\ . ( display characters statically on the screen )
\ . ( type ) ok ( then ) #65 ch #13 ch #66 ch

```

```

\ Block 296
( App: Mouse test ) empty vars dump mark
: kk vars dump hex $04 for ekey ;is ekey ekey ekey ekey ekey c next ;
: tt
: ps2 $D4 $60 pcl ;
: mm kstat ;
: ;iso

```

```

\ Block 297
\

```

```

\ Block 298

```

\ Block 299

\

\ Block 301

\ (Help screen)

\ (F1) show this help screen or the start shadow

\ (F2) toggle number base between decimal and hex

\ (F3) toggle seeb display of blue words (-) blue

\ (F4) editor, toggle colorforth / colorblind mode

\ Block 302

(App: Floppy disk driver) macro

: - \$35 1, \$FFFFFFF ; ;

: delay \$E1E6 2, ;

: p@ a! dup \$EC 1, delay ;

: p! a! \$EE 1, delay drop ;

: 1@ \$8A 2, ;

: 1! a! \$0288 2, drop ; forth

: on \$1C \$03F2 p! ;

: off \$00 \$03F2 p! ;

: err -if off warm ; then drop ;

: msr \$03F4 p@ \$C0 and ;

: out \$00100000 for msr \$80 or drop if *next \$00 - ; then \$03F5 p! pop drop 0 ;

: in \$00100000 for msr \$C0 or drop if *next \$01 - ; then \$03F5 p@ pop drop 0 ;

: cmd for out err next ;

: conf \$00 \$70 \$00 \$13 \$04 cmd ; \$03 \$A2 \$03 \$03 cmd ;

: sense \$08 \$01 cmd ; nload off

\ Block 303

\

\ : - (ones complement, sets flags)

\ : delay (dummy write, some hardware seems to need this)

\ : on - (activate floppy)

\ : off - (turn motor off, reset FDC)

\ : err n - (warm start if SF set)

\ : msr - n (get main status register)

\ : out n - ? (write a byte to the FIFO, return error on timeout)

\ : in - n ? (read a byte from the FIFO, return error on timeout)

\ : cmd x n - (send n bytes to the FIFO)

\ : conf - (some FDC commands,)

\ : spec -

\ : sense - (see documentation for details)

\ Block 304

(Floppy disk driver)

: clrfifo in -if drop ; then drop drop clrfifo ;

: clrintr sense in err \$80 and drop if clrfifo ; then clrfifo clrintr ;

: wait sense in err \$80 and drop if clrfifo wait ; then clrfifo ;

: cal \$00 \$07 \$02 cmd wait ;

: reset /flop \$03 \$A2 \$03 \$03 cmd \$00 \$70 \$00 \$13 \$04 cmd ;

: init on pause spec conf clrintr cal ;

: xfer for in err over 1! \$01 + next drop ;

: rd init push \$FF \$1B \$12 \$02 \$01 \$00 pop \$00 \$E6 \$09 cmd block \$04 * \$0400 \$12 * xfer off ;

: readid \$00 \$4A \$02 cmd \$07 for in err next clrintr ;

: version \$10 \$01 cmd in err \$90 or drop if \$02 - ; then 0 ;

\ Block 305

\

\ : clrfifo - (discard all remaining input from the FIFO)

\ : clrintr - (clear all pending interrupts)

\ : wait - (wait for interrupt)

\ : cal - (calibrate: move head to track 0)

\ : reset - (put FDC back to original state)

\ : init - (initialize controller)

\ : xfer a n - (reads n bytes from the FIFO to byte address a)

\ : rd b c - (reads cylinder c to block b)

\ : readid (for debugging)

\ : version - ? (tests if your FDC supports enhanced commands)

\ Block 314

```
( EEEEEEE qkqq )
```

```
\ Block 332
```

```
\ Block 333
```

```
\
```

```
\ Block 337
```

```
\
```

```
\ Block 344
```

```
\ Block 416
```

```
\ Block 428
```

```
\ Block 432
```

```
( Relative load blocks )
```

```
: ll ( -- ) blk @ load ;
```

```
: sect ( --asn ) blk @ block blk @ 2* #2 ;
```

```
: ss ( -- ) sect writes drop drop ;
```

```
: uu ( -- ) sect reads drop drop ;
```

```
#78 MagentaV lblk
```

```
: ld ( n- ) dup lblk ! load ;
```

```
: vv ( -- ) lblk @ edit ;
```

```
: help ( -- ) lblk @ #1 + edit ;
```

```
( Real Time Clock )
```

```
: rtc@ ( t-c ) $70 p! $71 p@ ;
```

```
: rtc! ( ct- ) $70 p! $71 p! ;
```

```
: hi ( -- ) #10 rtc@ $80 and drop 0if hi ; then ;
```

```
: lo ( -- ) #10 rtc@ $80 and drop if lo ; then ;
```

```
( processor clock ) #3999 MagentaV khz
```

```
: calkhz ( -- ) hi lo time hi lo time - #500 + #1000 / dup khz ! ;
```

```
: ms ( n- ) khz @ * time + begin pause dup time invert + drop -if drop ; then end drop ;
```

```
: secs ( n- ) for pause lo hi next ; macro
```

```
: swapb ( w-w ) $E086 2, ; forth
```

```
: split ( w-cc ) dup swapb $FF and swap $FF and ;
```

```
\ Block 433
```

```
\
```

```
\ Block 434
```

```
( Mandelbrot Set )
```

```
: o 0 0 dep @ #1 max for vndp itr vdup vlen $F0000000 + drop -if *next drop drop hole @ ; then drop drop pop hue ;
```

```
: mh x @ swap scrnw for o wf+ inc @ u+ next nip ;
```

```
: mv y @ scrnh for mh inc @ negate + next drop ;
```

```
: +d #2 dep +! : -d #-1 dep +! dep @ #1 max dep !
```

```
: draw vframe frame ! mv data ;
```

```
: ok c show keyboard ;
```

```
: l inc @ scrnw #1 - #8 */ negate x +! draw ;
```

```
: u inc @ scrnh #1 - #8 */ y +! draw ;
```

```
: d inc @ scrnh #1 - #8 */ negate y +! draw ;
```

```
: r inc @ scrnw #1 - #8 */ x +! draw ;
```

```
: +z inc @ #3 max dup scrnw #1 - #8 */ x +! dup scrnh #1 - #8 */ negate y +! #3 #4 */ #3 max inc ! draw ;
```

```
: -z inc @ #1000000 min dup scrnw #1 - #8 */ negate x +! dup scrnh #1 - #8 */ y +! #4 #3 */ inc ! draw ;
```

```
: hh home draw ; : hh2 h0 draw ;
```

```
: h keypd nul nul accept nul -d nul nul +d l u d r -z hh hh2 +z nul nul nul nul nul nul nul nul $2500 , $2B000023 , $0110160C , $2B181423 , #0 , #0 , #0 ,
```

```
\ Block 435
```

```
\ ( More Mandelbrot )
```

```
\ ( ludr move the cursor left right up down )
```

```
\ ( - + top row change depth detail )
```

```
\ ( - + bottom row change zoom )
```

```
\ ( h centres the image to the home location )
```

```
\ ( 0 resets depth and zoom )
```



```

\ Block 459
\

\ Block 491
\

\ Block 500
( App: Icons font editor ) empty
#0 MagentaV ic

<-- Unknown Blue token = AC80000E gc
<-- Unknown Blue token = AC80000E gc

: showall ( -- ) #0 #0 #448 at #256 for dup emit #1 + next
  drop ic @ #42 /mod #24 * #448 + swap #16 *
  2dup at #16 #24 v+ red box ;

\ Block 501
\ ( Draw big-bits icon )
\ : @w a-n ( fetch 16-bit word from byte address )
\ : !w na ( store same )
\ : *byte n-n ( swap bytes )
\ : ic -a ( current icon )
\ : cu -a ( cursor )
\ : sq ( draw small square )
\ : xy -a ( current screen position, set by ) at
\ : loc -a ( location of current icons bit-map )
\ : 0/1 n-n ( color square depending on bit 15 )
\ : row a-a ( draw row of icon )
\ : +at nn ( relative change to screen position )
\ : ikon ( draw big-bits icon )
\ : adj nn-nn ( magnify cursor position )
\ : cursor ( draw red box for cursor )
\ : ok ( background task to continually draw icon, icon number at bottom )

\ Block 503
\

\ Block 504
( App: Stack usage analyser )

: oneline ( a-- ) cr dup $6600 - $08 * $6800 + blue h.4 space yellow $20 type ;
: ok show blue page text #8 lm #1024 rm
  stacks $10 for dup oneline $20 + next drop
  keypad ;
ok

\ Block 506
( App: Server tasks )
#0 MagentaV var1
: ttsv1 serv1 #1000 ms #1 var1 +! ;

: ksv1 isrv1 ;
ttsv1

#0 MagentaV var2
: ttsv2 serv2 #2000 ms #1 var2 +! ;
: ksv2 isrv2 ;
ttsv2

: ttclr #0 var1 ! #0 var2 ! ;

: ttstop isrv1 isrv2 ;

lblk @ edit

\ Block 507
\

\ Block 508

```

```

( 23 ) ( Apr ) ( 23 ) ( 23 ) ( 23 ) + #16 #1 type #512
  drop then cr 0if and $1F @ line o onelin blue then ; sq green if ? $8000
: 0/1 ;
: showal @ font * */ #8 #24 #16 ( n--a )
: tofont and $FF @ ic
: loc ; +at #17 * #16 #17 drop next 2* 0/1 for #16 *byte @w dup
: row ; sq blue then ; sq green if ? $8000
: 0/1 ; + @ font * */ #8 #24 #16 ( n--a )
: tofont and $FF @ ic
: loc ; +at #0 #17 box + #16 swap + #16 /mod $00010000 @ xy
: sq
  forth ; 2, $C486
: *byte ; drop 3, $00028966 a!
: !w ; 3, $8B66 : @w macro

\ Block 509
\ #2 MagentaV icr ( numbe ) ( icon )
\ ; cmove */ #8 #24 #16 swap tofont swap tofont
\ : fcopy
\ ; d keypa l showal h.n #2 emit $78 emit $30 . green dup space emit dup @ ic ef
\ white at #400 #400 box #424 #416 ef at #400 #400 blue text ikon at dup #18 r curso
\ page show
\ : ok ; box + #52 u+ #52 red at over over adj adj /mod #16 @ cu r
\ : curso ; swap * #17
\ : adj ; drop next + #2 row for #24 loc
\ : ikon eu
\ : aoeuao

\ Block 510
( Sandbox >< any old ASCII <=> )

: >r push ;
: r> pop ;

: test ( your code here ) ;

\ Block 511
\ ( Help screen )
\ ( F1 ) show this help screen or the start shadow
\ ( F2 ) toggle number base between decimal and hex
\ ( F3 ) toggle seeb display of blue words ( - ) blue
\ ( F4 ) editor, toggle colorforth / colorblind mode
\ ( F5 ) rsn...
\ ( F6 ) shows the last block edited

\ Done.

```

Appendix D “Coloring Forth”

Coloring Forth

Because we must deal with the unknown, whose nature is by definition speculative and outside the flowing chain of language, whatever we make out of it will be no more than probability and no less than error.
 — EDWARD SAID
 Beginning, Intention and Method

Motivation

Core Words

Specials

bye

Quit ColorForth.

Stack

No effect

ColorForth Source

bye

Assembler

```
Bye:
  push  0
  call  ExitProcess
```

Macros

```
macro2 dd offset semi
        dd offset cdup
        dd offset qdup
        dd offset cdrop
        dd offset then
        dd offset begin
```

```
; semi
```

Overview

Semicolon – terminates current definition.

Implementation

Implementation is non-trivial – it provides both tail-recursion support and some optimization. If the last compiled item was a `call` to a word, it's being replaced with a `jmp`. Otherwise, `ret` is compiled.

`List` variable contains address of last compiled word.

H stands for HERE

```
H      dd  0

list   dd  0,
0

semi:
  mov    edx, [H]
  sub    edx, 5
  cmp    [list], edx
  jnz    @f
  cmp    byte ptr [edx], 0e8h
  jnz    @f
  inc    byte ptr [edx] ; jmp
  ret
@@: mov    byte ptr [5+edx], 0e3h ; ret
  inc    [H]
  ret
```

Sample

```
Forth
x 1 2 + ;
y x x ;
```

Code

```

                                x:
008A07B5 8D 76 FC               lea     esi,[esi-4]
008A07B8 89 06                 mov     dword ptr [esi],eax
008A07BA B8 01 00 00 00        mov     eax,1
008A07BF 05 02 00 00 00        add     eax,2
008A07C4 C3                   ret

                                y:
008A07C5 E8 EB FF FF FF        call    x
008A07CA E9 E6 FF FF FF        jmp     x
```

This sample deserves some explanation.

EAX contains the topmost element of data stack. ESI points to the second element. In order to put the value 1 onto stack, we have to store current topmost element in memory and decrement stack pointer, and only then load the constant into EAX. This operation takes 2 Pentium commands, 5 bytes, XXX ticks . Not so bad.

As we can see, 2 + is compiled into something shorter and better, we'll look at literal optimization later.

Now, for the word X the semicolon ; has compiled ret, while for Y the second call to X has been replaced with a jump.

dup cdup

Implementation

As we can guess from the code below, cdup stands for "compile dup". It compiles 5 bytes onto the top of the dictionary, and we have seen these 5 bytes above. So, dup is implemented as a macro, which compiles code to push the topmost element from EAX onto in-memory stack.

```
cdup:
  mov     edx, [H]
  mov     dword ptr [edx], 89fc768dh
  mov     byte ptr [4+edx], 06
  add     [H], 5
  ret
```

Traditional Forth implementation could look like this.

```
hex
: dup 89fc768d , 06 c, ; immediate
```

?dup qdup

Implementation

```
qdup:
  mov     edx, [H]
  dec     edx
  cmp     [list], edx
  jnz     cdup
  cmp     byte ptr [edx], 0adh
  jnz     cdup
  mov     [H], edx
  ret
```

This code looks whether the last compiled instruction was 0adh, which stands for

```
lods    dword ptr [esi]
```

And this is nothing else than a `drop` – move second element into the top of stack register, and increment stack pointer. So, `?dup` works as `dup`, though if last compiled instruction was `drop`, it shifts `HERE` one byte back – actually, “uncompiles” the `drop`.

This trick is used for optimizing macros – immediate words – that compile code with stack notation (`-- n`), for example, `0`, `A`, and `pop`, following words, which take one item off stack (`n --`) – for example, `push` (traditional `>R`), `!` or `A!`.

```
0 ?dup c031 2, ;
a ?dup c28b 2, ;

pop ?dup 58 1, ;

! ?lit if ?lit if 5c7 2, swap a, , ; then 589 2, a, drop ; then a! 950489 3,
0 ,drop ;
push 50 1, drop ;
a! ?lit if ba 1, , ; then d08b 2, drop ;
```

The macro `0` puts zero onto stack. It compiles into

```
xor     eax, eax
```

`A` puts the value of the address register onto stack. Corresponding Pentium code is


```
mov     eax, edx
```

Let’s consider an example

```
x1 here 2/ 2/ dup push a! 0 a ! pop @ ;
```

This code moves values 1 and 0 into the cell on the top of the dictionary.

here	008A07CF E8 8B 12 B6 FF	call	here (00401a5f)
2/	008A07D4 D1 F8	sar	eax,1
2/	008A07D6 D1 F8	sar	eax,1
push	008A07D8 8D 76 FC	lea	esi,[esi-4]
	008A07DB 89 06	mov	dword ptr [esi],eax
	008A07DD 50	push	eax
drop	008A07DE AD	lods	dword ptr [esi]
a!	008A07DF 8B D0	mov	edx,edx
0	008A07E1 B8 00 00 00 00	mov	eax,0
dup	008A07E6 8D 76 FC	lea	esi,[esi-4]
	008A07E9 89 06	mov	dword ptr [esi],eax
a	008A07EB 8B C2	mov	eax,edx
!	008A07ED 8B D0	mov	edx,edx
	008A07EF AD	lods	dword ptr [esi]
	008A07F0 89 04 95 00 00 00 00	mov	dword ptr
pop	[edx*4],eax		
@	008A07F7 58	pop	eax
;			



```

008A07F8 8B 04 85 00 00 00 00 mov     eax,dword ptr
[eax*]
008A07FF C3                      ret

```

Implicit `dups` and `drops` are highlighted with light blue. In future I will be replacing Pentium instructions with `dup` and `drop` macros. It's interesting to notice that `dup` is 5 bytes, while `drop` – only one.

This example, though a bit artificial, illustrates how address register and store-fetch pair works, as well as introduces “address as offset from 0 in cells” and “address as offset from 0 in bytes”. I'll be calling these cell address and byte address.